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BOTRYTIS AND SCLEROTINIA: THEIR RELATION TO CERTAIN PLANT DISEASES AND TO EACH OTHER.

RALPH E. SMITH.

(WITH PLATES XXV–XXVII AND THREE FIGURES)

IN connection with the work of the Hatch Experiment Station of the Massachusetts Agricultural College, a disease of hothouse lettuce has been under investigation for several years. The practical results of this investigation will appear in a bulletin of the station. It is the purpose of the present article to present some results of this study which seem to have a value beyond that of their practical relation to the lettuce disease, and to discuss these results, together with some obtained by other investigators, with a view to clearing up some unsettled points in the life history of certain fungi.

The question of the relation of certain species of the Polyactis section of the genus Botrytis to certain species of Sclerotinia is no new one. The literature of plant diseases, especially in Europe, abounds in descriptions and discussions of cases of plant diseases where one or the other or both of these forms appeared, and considerable difference of opinion has resulted as to their real relations to the disease and to each other. In this contention are involved principally two species of Sclerotinia, namely: *S. Fuckeliana* De By. and *S. Libertiana* Fckl., and one species of Botrytis, *B. cinerea* Pers. (*B. vulgaris* Fr., and numerous other synonyms). Largely on the authority of De Bary,

Botrytis cinerea has been considered the conidial form of *Sclerotinia Fuckeliana*, and the existence of any such conidial form of *S. Libertiana* has been denied. Some investigators have disputed this, however, claiming that in certain cases *Botrytis cinerea* has developed in undoubted connection with *Sclerotinia Libertiana*, thus casting doubts on the distinctness of *S. Fuckeliana*. The present article contains a description of the investigation of the above mentioned lettuce disease, in so far as it bears on this subject, together with some other observations made by the writer, and abstracts of descriptions of several similar diseases investigated by others.

1. The lettuce disease.

BIBLIOGRAPHY.

1. HUMPHREY, J. E. The rotting of lettuce. Rept. Mass. State Exp. Sta. 9: 219. 1892.
2. JONES, L. R. (*a*) Lettuce mildew and lettuce rot. Rept. Vt. Exp. Sta. 5: 141. 1892.
(*b*) Lettuce rots. Rept. Vt. Exp. Sta. 6: 84. 1893.
3. TAFT, L. R. Lettuce mildew. Am. Gard. 15: 375. 1894.
4. GALLOWAY, B. T. The growth of lettuce as affected by the physical properties of the soil. Agrl. Science 8: 302. 1894.
5. PAMMEL, L. H. Diseases of lettuce and radishes. Am. Gard. 16: 150. 1895.
6. BAILEY, L. H. Lettuce. Bull. Cornell Univ. Exp. Sta. 96: 387. 1895.
7. HALSTED, B. D. Some of the more injurious fungi upon market-garden crops: Lettuce. Rept. N. J. Agrl. Coll. Exp. Sta. 7: 349. 1895.
8. SELBY, A. D. Lettuce rot. Bull. Ohio Exp. Sta. 73: 221. 1896.
9. STONE, G. E., and SMITH, R. E. (*a*) "Drop" of lettuce. Rept. Hatch Exp. Sta. Mass. Agrl. Coll., 9: 79. 1897.
(*b*) The "drop" of lettuce. Rept. Hatch Exp. Sta. Mass. Agrl. Coll. 10: 55. 1898.
(*c*) Further considerations in regard to the "drop" in lettuce. Rept. Hatch Exp. Sta. Mass. Agrl. Coll. 11: 149. 1899.
10. KINNEY, L. F. Garden lettuce and its cultivation. Rept. R. I. Exp. Sta. 10: 270. 1898.
11. GARMAN, H. A method of avoiding lettuce rot. Bull. Ky. Exp. Sta. 81: 3. 1899.

In the Report of the Massachusetts Experiment Station for

1891 Humphrey (1) described a disease of greenhouse lettuce, from which the following is an abstract:

> The trouble ordinarily appears first upon the stem of the plant, about at the surface of the soil. Here may be seen at first a soft, dark, decayed spot, which rapidly spreads, penetrating the stem and involving next the bases of the lower leaves. The latter, being thus cut off from the plant by the decay of their bases, usually dry up. With the further progress of the decay the center of the head, with the tender inner leaves, becomes attacked, and soon collapses into a fetid, slimy mass. In the decaying tissue one can often recognize fungus threads, and if they are left undisturbed, there appear on the decayed remains the fruiting threads and spores of a fungus; always the same. . . . . The fungus in question is one of the imperfect forms known as Botrytis or Polyactis. . . . . In its development, so far as observed, and in the details of its structure, this fungus appears to agree with the form known as *Botrytis* (*Polyactis*) *vulgaris* Fr.; and is with little doubt the conidial stage of some sclerotium-producing Peziza (Sclerotinia).

Since the above was written the lettuce-forcing industry in the vicinity of Boston has largely increased, and forms today one of the most important agricultural industries in the state. Diseases of the crop have naturally increased proportionally. It is evident that the trouble described by Humphrey covers what is now generally known in the lettuce district as the "drop," and probably also more or less of another disease distinguished by the growers as "black root." The "drop" is the worst obstacle to lettuce growing in the Boston district. Its general nature is described in the quotation from Humphrey. Plants growing finely and approaching maturity suddenly collapse, the stem at the surface of the ground and the bases of the leaves are found to be rotted, and in a day or two the plant is completely gone. Plants afflicted with the real "drop" never recover. In most of these sudden cases, however, no black spot appears on the stem as described by Humphrey, nor does any external change in appearance take place except that a white, mould-like fungus mycelium usually appears and grows vigorously upon the surrounding soil. This Humphrey does not mention, though it seems probable that he would have done so if it had occurred in the cases observed by him, as it is very striking. Careful study of these diseases show that many cases of "black root" come

closer to Humphrey's description. This trouble appears to start in some injury to the plant, such as the breaking off of a leaf, or where the plants grow poorly and the outer leaves die off. Starting in some such way a fungus growth develops which gradually works down into the stem on the side from which it started, producing a black, decayed spot, just as described by Humphrey. A growth of Botrytis appears on the affected parts, but the vigorous growth on the soil does not appear. The ultimate fate of such plants depends largely on the management of the greenhouse. If the soil is kept dry and the temperature low no great loss results, but should a period of high temperature and considerable moisture occur the plants soon "drop" in the characteristic manner. A trouble of this sort appears to be common wherever hothouse lettuce is grown. It has generally been ascribed to *Botrytis vulgaris*, largely on Humphrey's authority, and the idea appears to be general that it can be held in check by proper handling of water and ventilation. Thus Humphrey says:

> It is evident that the thorough and careful culture and vigilant supervision of the plants are essential to the control of the disease in question . . . . with a crop well nourished and well cared for one may legitimately expect practical freedom from loss by rotting.

The "lettuce rot" described by Jones (**2**) does not appear to be the "drop," although ascribed to *Botrytis vulgaris*. The trouble described by Taft (**3**) as caused by *B. vulgaris* may include the "drop," but the name "mildew" is ill-chosen. Galloway (**4**), referring to the Boston soil, says:

> Wet rot of the lower leaves and rotting of the stems and consequent wilting of the plant are seldom troublesome in this soil if properly handled, because the surface is at all times comparatively dry. Wet rot is produced by *Botrytis vulgaris*.

Bailey (**6**) has the same idea when he says:

> This lettuce rot is due to a fungus (*Botrytis vulgaris*) which lives upon decaying matter on the soil, but when the house is kept too warm and damp, and the lettuce becomes flabby, it invades the plant and causes irreparable damage. There is no remedy, but if the soil is sandy and "sweet" and the

house properly managed as to moisture and temperature, and top dressings of manure are avoided, the disease need not be feared.

Bailey's illustration shows a typical case of "drop." If these statements are to be believed the condition of affairs in many lettuce houses about Boston can but reflect seriously on the skill of their owners. The disease is there and in abundance, to all appearances the same trouble as described by Humphrey, Galloway, and Bailey. In some houses it is much worse than in others but the fact is undeniable that even in the houses of some of the best growers, men who possess a practical knowledge of their special crop second to none, the disease is almost unchecked. Evidently, therefore, *Botrytis vulgaris* is a more serious parasite than is generally supposed, or else some other organism or agency is at work, producing a similar effect.

The first cases of the disease examined by the writer agreed very well with Humphrey's description. The plants were completely collapsed and the stems and bases of the leaves soft and rotten. The affected tissue was filled with a vigorous mycelium (*fig. 51*). This mycelium was composed of large, branching, septate, hyaline filaments, filled with granular protoplasm, but with numerous vacuoles in the older portions. The larger filaments averaged about 13μ in diameter. On the borders of affected tissue filaments could be seen advancing (*fig. 50*). When placed in a moist chamber over night, the plants became covered in the affected parts with a vigorous growth of the conidial form, *Botrytis vulgaris* Fr. This growth, to all appearances, originated directly in the parasitic mycelium which had destroyed the plant. The conidiophores developed from the interior filaments (*figs. 13–17*). *Fig. 18* shows the development of the branches, and *figs. 1* and *2* represent a typical conidiophore of this species. The peculiar branching forms known as "organs of attachment" (*figs. 19–26*) were also abundantly produced from the mycelium on affected plants and in cultures, which could readily be made on prune juice, prune bread, prune gelatine or agar, boiled fruits or vegetables, or almost any nutrient substance. Contrary to Humphrey's results, sclerotia

were produced abundantly on affected plants and in cultures. These were very small and insignificant, but numerous in every case.

Humphrey's conclusions that the disease is caused by *Botrytis vulgaris* appears to have been generally accepted by all who have written concerning this disease. It is very probable that in some of the citations given above the disease was not the real stem rot or "drop," but simply a case of Botrytis on the leaves, as often occurs on all kinds of plants when growing poorly or under unfavorable conditions. But in many of the references it is evident that the typical stem rot was found and ascribed to Botrytis. In no case was any extended investigation made. Early in the writer's study of this disease it became evident that whatever the cause might be, many cases occurred in which no Botrytis could be found, although otherwise the disease was very typical. Extended observation of a very large amount and variety of material from various sources has shown the existence of what may be called three forms of the typical disease. This excludes some other lettuce troubles of a more or less similar nature.

THE BOTRYTIS TYPE.

This form of the disease has already been described in a general way. It should be clearly distinguished from cases where Botrytis grows locally, more or less as a saprophyte, or even as a true parasite, upon the outer leaves. The rotting of the stem and collapse of the leaves and head is the characteristic of this and all types of the real "drop." *Botrytis vulgaris* is well known as one of the fungi, though not, perhaps, the most common, which cause the death of young seedlings and cuttings by what is known as "damping off," a trouble entirely similar to the "drop" in its effect, being a rotting of the stem at the surface of the ground. The principal difference between "damping off" and "drop" from a practical standpoint is in the age of the plants affected. "Damping off" of lettuce seedlings is common and may often be traced to Botrytis. It would not

seem remarkable, therefore, for so similar a disease as the "drop" to be caused by the same fungus. But of course the occurrence of this so common species upon affected plants comes far from proving it to be the parasite, and especially since many cases of the typical disease occur where no trace whatever of this fungus, or at least of its conidial form, can be found, Humphrey's conclusions cannot be accepted without further and more definite proof. The most convincing case in this respect seen by the writer was that of a crop of lettuce grown in one of the station greenhouses in the winter of 1898–9. The "drop" had been introduced into this house for purposes of study in 1897 and had been abundant in each crop since then. In no case, however, had any Botrytis appeared. Meantime, a method of treatment had been developed by which this no-botrytis type of the disease was completely held in check. The treatment consisted in sterilizing the soil by means of steam, and crop after crop was grown, with or without the disease at will. When this crop was set out the plants were overgrown and "spindling," having been too long in the flats. Consequently the outer leaves died off and the plants received a severe set back. Added to this the house was not properly ventilated and on several occasions the temperature was much too high. Soon after being set out the plants began to "drop," and in a few weeks the majority of them, in treated and untreated soil alike, were gone. Affected plants showed a mycelium in the stem indistinguishable from that in all other cases. Organs of attachment occurred as usual. Botrytis was abundant on every plant, especially when kept over night in a moist chamber. No mycelium was visible upon the surface of affected plants nor did it spread to the surrounding soil, and it could not be seen that the disease spread from plant to plant. The leaves were scarcely or not at all affected except at the very base and the rotting was almost entirely confined to the stem, the rest of the plant drying up. There is no reason to doubt that these plants were affected primarily with *Botrytis vulgaris*, originating presumably from conidia in the air, and such is believed to have been the case. It appeared to be essentially a

case of belated "damping off," made possible by the weakened condition of the plants.

Cultures made from affected tissue from these plants and from the Botrytis conidia gave similar results. A rather scanty mycelium developed, bearing numerous organs of attachment and but few conidia. Often no spores developed until after several weeks, even in cultures made directly from conidia. Compared with cultures made from ordinary saprophytic *Botrytis vulgaris*, these seemed to show that as the fungus takes on a parasitic nature it produces fewer conidia and more organs of attachment, though it is extremely variable and uncertain in these respects. Sclerotia were sparingly produced in almost all cultures made from this material. These appeared first as reddish, blister-like elevations in the substratum, gradually becoming black and hard. They were mostly longer than broad, thin, firmly attached to the substratum and inseparable from it. *Text fig. 1 f* shows some of these sclerotia grown on gelatine, portions of which are still attached to them. The photograph does not bring out clearly the size and form of the single specimens, as it is impossible to separate them cleanly. Thus, *text fig. 1* f^a is a piece of gelatine having on its surface two long, thin, narrow sclerotia lying parallel to one another, while f^b consists of several sclerotia with more or less gelatine. *Fig. 44* also represents some of these forms, but fails to bring out their thinness. If placed in wet sand soon after being formed these sclerotia produced an abundant crop of Botrytis conidiophores and conidia. The ability to produce conidia appeared to be lost with age, and after a few months drying the development was largely of mycelium, though this was rather scanty.

In order to determine still more fully the relation of Botrytis to the lettuce disease some investigations were made along the line of infection experiments. Humphrey reports such to have been unsuccessful. Experiments on early mature lettuce plants gave the following results.

1. Pieces of affected plants buried in the soil beside healthy plants generally produced the disease.

2. Diseased plants from the lot just described, which appeared to have a pure Botrytis disease, did not have this effect.
3. Water containing abundant conidia poured down into the head produced no effect.
4. The same result was obtained when the leaf stalks were

FIG. 1.—*a*, sclerotia of *Sclerotinia Libertiana*: *b*, *c*, sclerotial crust of lettuce fungus; *d*, small sclerotia from lettuce fungus; *e*, sclerotia of *S. Libertiana* from alfalfa; *f*, sclerotia of *Botrytis cinerea*.

cut into so that the conidia came into contact with wounded tissue.

5. Conidia dusted all over plants in great abundance had no effect.
6. Plants treated as in 5 but covered with a bell jar became affected in the leaves, which gradually died and rotted away, but the stem was unaffected and no typical "drop" resulted.

7. When the stem was cut into at the surface of the ground and mycelium and conidia inserted, no effect was apparent.

From these experiments it appears that the typical "drop" cannot be produced from Botrytis conidia in vigorous lettuce plants under ordinary conditions.

The following experiments were made with lettuce seedlings. A dish of soil was sterilized and then thoroughly inoculated with fresh Botrytis conidia. Lettuce seed was then sown. The plants came up well and remained entirely unaffected. The soil was then sprinkled heavily with conidia among the seedlings, with the result that one "damped off." The stem was permeated with a mycelium entirely similar in appearance to that found in the "drop." A portion of this is shown in *fig.* 27 (cf. *fig.* 51).

The dish was then covered with a bell jar and kept very moist, but no more plants were affected. Prune juice containing conidia was then poured amongst the plants and the dish kept in the open air. "Damping" at once set in, and in a few days all the plants succumbed in the characteristic manner. Cultures made from these plants on prune and turnip showed the parasitic peculiarities of Botrytis already referred to. A considerable mycelium was produced at first but very few conidia until later. Raw turnip was readily attacked and caused to rot. This experiment corroborates Kissling's[1] results in regard to *Botrytis cinerea* that conidia are unable to, or at least do not readily, attack living tissue except after previous saprophytic nourishment.

In respect to the general question as to the relation of Botrytis to the "drop," these results seem to show that the disease is not produced in vigorous plants by direct infection from conidia in the air or soil, although in the case described above, where the vitality of the plants was very low, such appears to have been the case. The same conclusion may be deduced from the usually sucessful result of sterilizing the soil. There appears to be no doubt that the cases where "black root" develops into the "drop" belong to this form of the disease, and also the trouble which Humphrey, Galloway, and Bailey had in mind in referring

[1] Hedwigia **28**: 227. 1889.

to its treatment. Were this the only form to occur it would cause little trouble in the Boston district, as it is almost unknown there except for an occasional case of "black root."

THE NO-BOTRYTIS TYPE.

Among all the cases of the disease examined by the writer, those in which Botrytis appeared have been by far the exception. In the type of the disease most prevalent in Massachusetts no conidial form whatever can be found. In its general effect the disease is entirely similar to that already described and indistinguishable from it. Affected plants wilt and collapse and in a few days are entirely destroyed. The usual mycelium is found in the stem. It is also usual to find an abundant, white, woolly mycelium proceeding from affected plants to the surrounding soil where it flourishes luxuriantly for a time, often spreading to and attacking adjacent plants. In fact it is evident that whatever form of reproduction this fungus may possess its principal mode of spreading in the greenhouse is by growth in the soil. Wherever one plant is attacked the neighboring ones almost always follow, and the mycelium grows luxuriantly upon the soil, extending from plant to plant. On coming into contact with a healthy leaf it spreads over the surface, forming numerous organs of attachment (*fig. 31*). *Fig. 29* shows in cross section the result of this, the epidermis breaking down and the filaments penetrating and destroying the leaf. Sclerotia are formed in considerable abundance on affected plants, especially on the stem and beneath the leaves, but they are very small and easily overlooked in the soil. Cultures are easily made with bits of affected tissue or mycelium, and hundreds have been made in this way with no sign of Botrytis. Such cultures produce a considerable mycelium, more abundant on bread than on gelatine, and very numerous sclerotia. This mycelium is composed of filaments indistinguishable from those in the botrytis form. Organs of attachment are numerous and entirely similar. The sclerotia are very small, mostly about the size of a pin head. Some are a little larger, but thin and irregular in shape, while often a sort

of black sclerotial crust is formed, an inch or more in diameter, but not much thicker than paper. *Fig. 42* and *text fig. 1 d* show the small sclerotia of this type, and the crust-like growth is shown by *text fig. 1 b* and *c*, and by *fig. 43*. A clear distinction can be seen between the formation of sclerotia in this and in the botrytis form. Here they first appear as white specks in the mycelium, gradually becoming black and hard. They are not as long as those of the other form, and lack entirely the very characteristic blister-like connection with the substratum, being entirely distinct from it and imbedded in the mycelium. They are also produced much more abundantly. Many trials were made to obtain further development from these sclerotia. When placed on moist sand they usually produced a growth of mycelium, more copious from old specimens than fresh ones. Old dry material a year old grows luxuriantly when kept moist for a few days, producing much more mycelium than the Botrytis sclerotia. What might be called secondary sclerotia are also produced on such growths. On the surface of clean sand, on moist filter paper, or even on the bare bottom of a glass dish, when kept covered and moist, the mycelium coming from a sclerotium produces often a considerable number of smaller ones. The same result is often seen when a piece of affected tissue is placed in a moist chamber (*fig. 45*); and upon the surface of the soil about, and especially beneath the leaves of the affected plants, such secondary sclerotia are commonly produced. Being so small, however, they are difficult to distinguish in the latter case. Other than this no development has been obtained from these sclerotia except in one case. One of the largest specimens, about 3^{mm} in diameter, after being in the sand for some time, threw up a slender stalk (*fig. 35*). This reached a height of nearly 1^{cm}, but then withered and faded away without attaining any farther development.

Since no reproductive structures of this form could be obtained, infection experiments were only possible by using diseased tissue or masses of mycelium as infective material. Such experiments were almost invariably successful. Using plants

which showed this type of the disease in its purest form, or cultures made from them, it was found that when bits of diseased tissue were buried in the soil beside healthy plants, or inserted in cuts in the stem, the disease was at once produced. It was further found that if affected plants or portions of them were buried in a flower pot and lettuce plants set in, the latter would soon begin to die off and all eventually succumb, the mycelium soon appearing upon the surface of the soil in the characteristic manner. With sclerotia, pure mycelium, or pieces of sclerotia, the same results are obtained. In none of the experiments were the plants covered or placed under any conditions different from those of ordinary greenhouse culture. These results show plainly that this species or form is an active parasite, capable of causing the disease in the most vigorous plants at any age, but at the same time able to flourish under purely saprophytic conditions. It is likewise able to reproduce itself from year to year indefinitely by purely vegetative development, forming freely, either as a saprophyte or parasite, sclerotia which are able to survive all ordinary conditions[2] and produce the fungus anew. It would seem, in fact, that this is the only method of reproduction of this form. The results of sterilizing the soil have been already alluded to. It was found that when not less than three inches of the surface soil had been steam sterilized not a plant was affected, even in the worst infested beds. The only exception to this was the one crop where the pure botrytis type occurred. Plainly, therefore, the no-botrytis form depends very largely, if not entirely, upon saprophytic growth in the soil and the sclerotial resting stage for the continuance of its existence.

THE LARGE SCLEROTIA TYPE.

In a lot of lettuce plants sent by a gardener in eastern Massachusetts a third type of the "drop" was found. In this case the general nature of the disease was typical, and the parasitic

[2] Many results that relate to the biology of these forms are omitted here as they do not bear on the present subject.

mycelium indistinguishable from that found in other cases. No Botrytis appeared. The peculiarity of this form was that the sclerotia which were rather sparingly produced on the plants, were quite large and thick, much more so than in the ordinary no-botrytis type. In cultures numerous large, well-formed sclerotia appeared, some being an inch long and thick and solid (*fig. 41*, and *text fig. 1 a*). These sclerotia could be grown by the quart on suitable media, dishes of prune bread being especially favorable. Their development is similar to that of the smaller ones in the last type described. Beginning as a white, harder spot in the mycelium they gradually enlarge, becoming, when mature, black and hard. They have no connection with the substratum, being imbedded in the mycelium and easily separated from it. During their formation drops of a clear liquid usually appear on the surface, and in old cultures the sclerotia and mycelium often become incrusted with rod-shaped crystals of calcium oxalate. In cultures and on diseased plants organs of attachment are very abundant and entirely similar to those already mentioned.

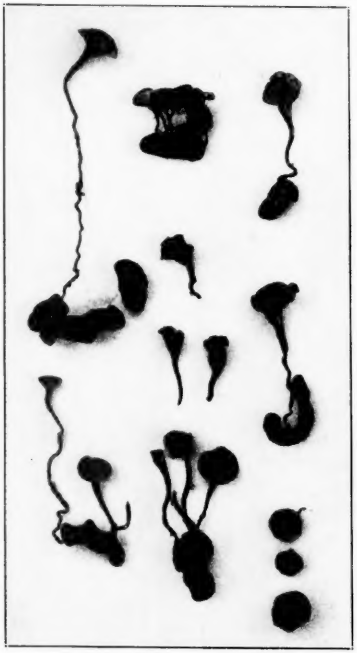


FIG. 2.—Sclerotia and apothecia of *Sclerotinia Libertiana*; slightly reduced.

When placed on wet sand these sclerotia soon began to throw up slender stalks, usually several from each, which expand into trumpet-shaped Peziza apothecia. These bodies varied somewhat in size and shape, as shown by the typical forms in *text fig. 2*.

The disks have the usual discomycetous structure as shown in section (*fig. 32*). Asci and paraphyses are shown more enlarged in *fig. 33*. This fungus was a typical form of *Sclerotinia Libertiana* Fckl. (*Peziza Sclerotiorum* Lib., etc.)

Similar infection experiments to those in the last case made with this material gave the same results. Diseased tissue or portions of mycelium never failed to produce the disease in healthy plants. No experiments have been made with ascospores in respect to infection. The conclusion is a safe one that *Sclerotinia Libertiana* is an active parasite of lettuce and, in some cases at least, the cause of the disease under consideration. The form just described, however, is far from common in greenhouses, and certainly does not occur in the great majority of cases of the "drop".

GENERAL CONSIDERATION OF THE CAUSE OF THE DISEASE.

These three types cover all the cases of the disease which have been seen by the writer. The last occurred in but a single lot of plants. The second represents the bulk of the disease in this state. The first in its purest form was found only in the single lot of plants described and occasionally in a few plants in a crop soon after setting. Cases are not rare, however, which appear to be a mixture of the first and second. Botrytis develops on affected plants but cultures from the most newly affected inner tissue give no Botrytis but characteristic growth of the no-botrytis form.

The observations thus far recorded are sufficient to establish the following statements:

The "drop," in the majority of cases, is a strictly parasitic disease and attacks the most vigorous plants.

The ordinary Botrytis in its conidial form does not cause the disease except in exceptional instances.

Either of the last two forms described is able to cause the disease in a strictly parasitic manner.

The disease is spread and infection takes place most commonly by saprophytic growth through the soil.

The fungus which causes most cases of the disease is able to exist indefinitely in the soil by means of sclerotia, which may be formed either upon affected plants or by purely saprophytic growth in the soil and appear to form the usual, if not the only, mode of reproduction.

This fungus may be exterminated by heating the soil.

In exceptional cases the "drop" appears to have been caused by the conidial form of *Botrytis vulgaris*, but only in plants which were under unfavorable conditions.

The disease may be caused by a typical form of *Sclerotinia Libertiana* Fckl., but this is exceptional.

In all cases of the disease there is the closest resemblance in the effect on the plant and in the parasitic mycelium which attacks it, the latter applying to the filaments and the organs of attachment which they bear.

The most marked differences between the three forms are found in the production of Botrytis conidia in the first and its absence in the other two; in the production of the Peziza stage in the last; in the form and size of the sclerotia and the manner of their production; and in the general greater development of the mycelium and its spread over the soil in the last two types.

On the basis of these statements the following suppositions are possible as to the relations of these forms to one another and the real cause or causes of the disease.

1. The three types are caused by three distinct species of fungi which are peculiarly coincident in certain respects.

2. The three types are caused by three different forms of the same species, which accounts for the coincidences.

3. Two of the forms belong to the same species while the third is distinct but similar in certain respects.

CULTURES.

In order to test further these hypotheses a large number of special cultures were made which may now be described. The specific object of these experiments was to find out, by growing the three forms of fungi under various conditions, whether any

of the forms could be changed into any other, or to prove definitely that they are all distinct. To accomplish the former required that Botrytis be developed in a pure culture of one or both of the no-botrytis forms, that one or both of the typical no-botrytis forms be developed from Botrytis conidia, or that the typical *Sclerotinia Libertiana* be developed from the ordinary no-botrytis form or *vice versa*.

Growth on various media.—Cultures of the three forms were made on a considerable variety of substances to test their effect on the organisms. These substances included various fruit decoctions, bread soaked with various nutrient juices and decoctions, and boiled fruits and vegetables of many different kinds. A detailed account of these cultures is unnecessary as in every case the growth was typical of the original material and no marked changes appeared.

Effect of low temperature.—Here again no results were obtained. It was found that each of the forms, with proper nourishment, continued to grow almost down to the freezing point, but naturally with much less vigor at the lower temperatures. No other effect than this was observable with the no-botrytis forms. With Botrytis no conidia developed in cultures kept below 5° C., a feeble mycelium being the only growth. When put in a warm place, however, these cultures at once grew in the ordinary manner, producing abundant conidia.

Effect of darkness.—No marked effect was produced by growth in total darkness.

Effect of starvation.—Cultures made in pure gelatine with no nutrient addition showed nothing more marked than a feeble growth.

Effect of solidity of substratum.—This was tested by using nutrient agar of different degrees of solidity. Growth was not as vigorous upon the hardest grades, but no other effect appeared.

Effect of acid and alkaline media.—These experiments were made by using as a nutrient medium prune juice of different degrees of acidity and alkalinity. The decoction was first carefully neutralized by an experienced chemist, using sodium

hydrate and tartaric acid weighed out in the dry form and added to the prune juice in the proper amounts; the following series of flasks were made up: $\frac{1}{10}$, $\frac{1}{2}$, 1, 2, 3, 4, 5, and 10 per cent. acid, with similar alkaline series.

With Botrytis no results affecting the main question were obtained from these cultures. After four days good mycelium and conidia had developed in alk. $\frac{1}{10}$ per cent., neutral, and $\frac{1}{10}$, $\frac{1}{2}$, and 1 per cent. acid. Acid 2 per cent. had considerable mycelium, rather dense, and a few conidiophores. Acid 3, 4, and 5 per cent. had a smaller amount of dense mycelium, forming a compact membrane. Acid 10 per cent. had merest trace of development. Alk. $\frac{1}{2}$ per cent. had good mycelium, loose and flocculent, with some conidiophores around the edges. Alk. 1 per cent. about the same but with very few conidiophores. Alk. 2 per cent. poorer mycelium with woolly, flocculent appearance and no conidia. Alk. 3 per cent. merest trace of development. Alk. 4, 5, and 10 per cent. no growth. Two weeks later conidia were abundant in all the acids except the 10 per cent., which showed no growth. The alkalies had quite abundant conidia below 3 per cent., but from there on very little or no development. Acid 1 per cent. gave about as vigorous and typical a Botrytis growth as any. The contrast was very marked between acid 2–5 per cent. and alk. 1–2 per cent. The former formed a close dense membrane, while the latter was loose, woolly, and flocculent. No particular difference in the filaments could be seen with the microscope. While these results have some little general interest they gave no evidence as to a connection between Botrytis and other "drop" fungi. The no-botrytis fungus with small sclerotia showed no such striking differences in development in acid and alkaline media as did Botrytis. Its range of growth was about the same and the effect upon the mycelium was somewhat similar but by no means as marked. From one culture of this sort, however, a valuable result was obtained. This was a large flask of prune of considerable alkalinity but not made up in definite proportions. It was inoculated with mycelium from a pure culture of the small-sclerotia fungus, coming

originally from lettuce in a house which had never contained any other form of the disease. In this culture the usual small sclerotia were first produced, but later there appeared a considerable number of larger ones, appearing similar to those of *S. Libertiana*. A number of these were obtained and cultures made from them on ordinary prune bread, with the result that the typical large-sclerotia type developed. No spores of this type had ever been developed in the laboratory at the time this culture was made nor had any trace of the large-sclerotia form ever appeared in connection with any of the material used, so that there would seem to have been no possible chance for accidental infection. Consequently the only possible explanation seems to be that *Sclerotinia Libertiana developed directly from the small-sclerotia, no-botrytis form.*[3] (In this connection should be borne in mind the fact already mentioned that in one case one of the small sclerotia started to develop an apothecium just as in *S. Libertiana.*)

CONCLUSIONS.

From all the observations and experiments thus far recorded it is concluded:

1. That the lettuce "drop" in Massachusetts is caused by two distinct species of fungi, namely, *Botrytis vulgaris* Fr. and *Sclerotinia Libertiana* Fckl., which are remarkably alike in some respects and have an entirely similar effect upon the plant.

2. That the bulk of the disease is caused by a degenerate form of the latter species, which has almost entirely lost the ability to reproduce by spores but which is highly specialized as a vegetative, facultative parasite.

3. That the disease is caused by *Botrytis vulgaris* and the typical *Sclerotinia Libertiana* in mature plants only in rare instances; the former on account of its inability to attack vigorous plants under normal conditions, the latter because of its infrequent occurrence.

[3] It is not asserted that this result is to be attributed to the alkalinity of the culture medium.

4. That in many cases Botrytis develops as a saprophyte on plants primarily affected by the other species and is mistaken for the true parasite on account of the similarity of the mycelium.

5. That these forms and species can be distinctly separated by means of pure cultures, and distinguished from one another by the form and manner of growth of the sclerotia.

NOTE.—No reference has thus far been made to the internal structure of the sclerotia. De Bary (Morph. and Physiol. p. 31) draws a distinction between the Botrytis and *Scl. Libertiana* forms on the basis of structure, but the writer has not been able to establish this or make a uniform distinction. *Fig. 39* shows a section which might represent any of the forms.

Thus it appears from the study of this disease that *Sclerotinia Libertiana* has no connection with the Botrytis form in question, although at first sight this appeared to be undoubtedly the case. Confusion has arisen from the similarity in the parasitic mycelium of the two forms, their similar effect on the plant and their frequent simultaneous occurrence; coincidences most deceptive to superficial examination but easily explained on the ground of the close relationship between the two species. Too general conclusions should not be drawn from the case of this disease, however, without taking into consideration a number of very similar ones which have been described. The writer has been fortunate in obtaining material of a number of these diseases, as well as additional information concerning some of them, and has spent considerable time in comparing them with the results obtained from the study of the lettuce disease. Careful inquiry shows at once that much has been taken for granted in many of these cases and conclusions drawn which were based more on apparent probability and general appearances than actual proof. It must be conceded that in a number of cases which are mentioned hereafter the conclusion seems at first sight fully warranted that *Botrytis cinerea* is a stage in the life history of *Sclerotinia Libertiana*, so intimately are the two forms associated with one another and so similar are they in effect and many details of structure. But, as will presently appear, in every case which the

writer has been able to investigate or obtain full information about, as well as from his general study of the species of fungi concerned, the conclusions based on the study of the lettuce disease are fully substantiated. Three classes may be made of the diseases of this nature as follows: (1) diseases where both *Sclerotinia Libertiana* and *Botrytis cinerea* (*vulgaris*, etc.) appeared; (2) diseases attributed to Botrytis alone; and (3) diseases attributed to Sclerotinia alone.

II. Diseases attributed to Sclerotinia and Botrytis.

As a type of this class, which would include the lettuce disease, may be taken the disease of hemp described by Behrens and others.

HEMP DISEASE.

BIBLIOGRAPHY.

1. TICHOMIROFF, W. *Peziza Kaufmanniana;* eine neue, aus Sclerotium stammende und auf Hanf schmarotzende Becherpilz-Spezies. Bull. Soc. Nat. de Moscou.— : 294. 1868.

2. HAZSLINSZKY, F. *Polyactis infestans.* Grev. **6**: 77. 1877.

3. DE BARY, A. Ueber einige Sclerotinien und Sclerotinienkrankheiten. Bot. Ztg. **44**: 378. 1886.

4. BEHRENS, J. Ueber das Auftreten des Hanfkrebses in Elsass. Zeitschr. f. Pflanzenkrankh. **1**: 208. 1891.

5. SORAUER, P. (*a*) Die Schäden der einheimischen Kulturpflanzen. (Zeitschr. f. Pflanzenkrankh. **1**: 212. 1891.)
(*b*) Hanfkrebs. Pflanzenkrankheiten 289.

6. HILTNER, L. Einige durch *Botrytis cinerea* erzeugte Krankheiten. Inaug. Diss. 1892.

7. FRANK, A. B. Sclerotienkrankheit des Hanfes. Die Pilzparasitären Krankheiten der Pflanzen 499.

A disease very similar to that of the lettuce is described by Behrens (4) on hemp. For several successive seasons a stem rot of this plant was observed in Alsace. Affected stems were permeated with large, intercellular filaments, while upon the surface appeared sclerotia resembling the old form *Sclerotium varium*. In the interior cavity of the stem were also numerous sclerotia. Upon some affected plants a growth of *Botrytis cinerea* appeared,

the mycelium of which agreed entirely with that in the stem. In a moist chamber Botrytis appeared on many of the plants. Material received the following year showed no trace of Botrytis; otherwise the disease was exactly the same. Cultivated on bread the fungus produced abundant sclerotia but no Botrytis, while in the previous year the conidial form appeared in cultures regularly. The author concludes that the organism is similar to *Sclerotinia Libertiana* in every way except for the Botrytis conidia, which form is supposed to characterize *S. Fuckeliana*, and states that one of two cases is possible; either the Botrytis is secondary on stems affected primarily with *S. Libertiana*, or else the fungus occurs varyingly, with or without Botrytis conidia. The results of inoculation experiments with Botrytis conidia appeared to support the latter hypothesis, that the Sclerotinia may appear with or without Botrytis. Whether it should be called Fuckeliana or Libertiana the author was unable to decide.

Some time after the above was published, in the spring of 1898, the writer visited Dr. Behrens at Karlsruhe and was informed by him in regard to this disease that after more extended observation and consideration he inclined to the opinion the Botrytis and Sclerotinia might after all have been distinct species on the hemp, having no connection with one another.

Tichomiroff (1) found a disease of hemp in Russia with which that described by Behrens appears to be identical. He observed numerous sclerotia and named the form *Peziza Kaufmanniana*. No mention is made of a Botrytis stage. De Bary (3) found it possible to infect hemp with ascospores of *Sclerotinia Libertiana* and decided that *Kaufmanniana* was the same species.

Hazslinszky (2) found a fungus parasitic on hemp in Hungary which he named *Polyactis* (*Botrytis*) *infestans*. Behrens considered this as probably a form of *B. cinerea*, although the conidiophores, as figured by Hazslinszky, are articulated in a peculiar manner.

Hiltner (6) found a hemp disease with symptoms agreeing with those described by Behrens, Tichomiroff, and Hazslinszky, wherein no sclerotia appeared but abundant *Botrytis cinerea*.

The writer was unable to obtain material of this disease and consequently has no original information to offer concerning it. This case has been brought forward as one of the best examples of the connection between Botrytis and *Scl. Libertiana*, but Dr. Behrens' later statement changes the aspect completely. With his original conclusions discredited by himself there remains the fact that Tichomiroff and Hiltner found the disease caused respectively by Sclerotinia and Botrytis alone, and no proof is to be found that the two forms had any connection with one another in attacking this plant. The fact that Behrens found no Botrytis in connection with the disease during one season gives further evidence that this species was entirely distinct, though in similar effect and appearance.

RAPE DISEASE.

BIBLIOGRAPHY.

1. HAMBURG, E. A. *Peziza ciborioides* Fr., etc. III. Földniv. Erdec. **8**:509. 1880. (Bot. Centralb. **8**: 172. 1881.)

2. DE BARY, A. *loc. cit.* 458.

3. FRANK, A. B. Sclerotienkrankheit des Rapses. *loc. cit.* 493.

4. SORAUER, P. Die Sclerotienkrankheit des Rapses. *loc. cit.* 297

The disease of the rape plant described by Frank (**3**) is also one of interest in this connection. Plants were found to be affected by a rotting of the stem, the cortex and pith being filled with a fungous mycelium, soon becoming completely destroyed. Numerous black sclerotia were present in the pith cavity. The filaments of the mycelium were hyaline, filled with granular protoplasm with vacuoles, septate and branching profusely in all directions. The largest had a diameter of 20μ. The sclerotia were of irregular form and had a diameter of 2–10^{mm}. In places where the plants stood close together *Botrytis cinerea* often appeared upon the diseased portion of the stem. When affected stems were put under conditions of moisture this always occurred. The Botrytis hyphae seemed to arise without doubt from the interior filaments. Further development was obtained by placing sclerotia on moist sand, when they produced

apothecia, which the author attributes to *Sclerotinia Libertiana*. It was found possible to infect healthy rape plants with either conidia, ascospores, or mycelium, or by sowing the seed in a pot of earth containing diseased tissue. Seedlings were infected with Botrytis conidia and kept under a bell jar. They soon showed the disease as before. The author also cites the results obtained by Hamburg (1), who found it possible to infect healthy rape plants with ascospores of *S. Libertiana*, producing the disease with a development of Botrytis conidia, and he (Frank) concludes that the distinction of the two species *S. Libertiana* and *Fuckeliana* on the basis of presence or absence of the Botrytis form is impossible.

De Bary (2) discredits Frank's conclusions as to the connection between *S. Libertiana* and Botrytis.

This case seems to be the strongest argument in support of the connection between Botrytis and *Scl. Libertiana*. The writer has no personal knowledge of the disease. It should be pointed out, however, that Frank's results are really but little different from those obtained in the study of the lettuce disease where opposite conclusions were reached. The principal evidence in favor of the connection between the two forms is based on their simultaneous occurrence and the fact that the disease was induced in healthy seedlings kept under a bell jar by infection with Botrytis conidia, both of which facts apply equally well to the lettuce disease as already described. Nor are Hamburg's results any more convincing, since the appearance of Botrytis as a saprophyte on plants attacked by Sclerotinia is no unusual occurrence. The appearance of Sclerotinia (meaning sclerotia capable of producing Peziza) upon plants infected with Botrytis conidia would have carried great weight, but no such result has been obtained. The writer feels justified in stating in regard to this disease, on the testimony of those who have described it, and in the light of the similar cases which he has investigated and the general study of the species concerned, that no positive proof whatever is found herein that *Botrytis cinerea* and *Sclerotinia Libertiana* have any connection with each other.

POTATO DISEASE.

BIBLIOGRAPHY.

1. SMITH, W. G. (*a*) New form of disease in potatoes. Gard. Chron. N. S. **14** : 264. 1880.
(*b*) Disease of potatoes. Nature **28** : 299. 1883.
(*c*) New disease of potatoes. Diseases of field and garden crops 15.
2. Nature **28** : 231. 1883.
3. WILSON, A. S. (*a*) Disease of potatoes. Nature **28** : 343. 1883.
(*b*) Potato disease. Gard. Chron. N. S. **20** : 333. 1883.
4. BLYTT, A. Disease of potatoes. Nature **28** : 367. 1883.
5. DE BARY, A. *Loc. cit.* 436.
6. COHN, F. Illustr. landw. Ztg. 1887.
7. KIRCHNER, O. Die Stengelfäule, eine neue auftretende Krankheit der Kartoffeln. Würmtembergisches Wochenblatt für Landwirtschaft **30** :—. 1893.
8. RITZEMA BOS, J. (*a*) Kurze Mittheilungen über Pflanzenkrankheiten und Beschädigungen in den Niederlanden in den Jahren 1892 und 1893. Zeitschr. f. Pflanzenkrankh. **4** : 144. 1894.
(*b*) Kurze Mittheilungen, etc., im Jahr 1894. Zeitschr. f. Pflanzenkrankh. **5** : 286. 1895.
9. SORAUER, P., Editor. Einige Notizen über die in den letzten Jahren in Deutschland aufgetretenen Krankheitserscheinungen. Zeitschr. f. Pflanzenkrankh. **5** : 97. 1895.
10. REHM, H. Ascomyceten. Rabenhorst's Kryptogamen Flora **13** : 803.
11. FRANK, A. B. Sclerotienkrankheit der Kartoffel. *Loc. cit.* 500.

Kirchner (**7**) found potato plants which showed symptoms very similar to those in the lettuce, the stem rotting off just above the ground. Where the plants stood close together a vigorous growth of *Botrytis cinerea* appeared upon the affected parts, to which the author attributes the disease. No sclerotia were found. Ritzema Bos (**8**) found the same disease abundant in Holland. Cohn (**6**) notes a potato disease in Germany with very similar symptoms, but found sclerotia which seemed to belong to *Sclerotinia Libertiana*. The same is stated as being abundant in Norway. A "new disease of the potato" has been described by Smith (**1**), Wilson (**3**), and Blytt (**4**). The diseased plants became covered with a thick, felt-like growth of fungous mycelium, and in a short time stem and leaves were completely destroyed. Immersed in the mass of mycelium

appeared numerous black sclerotia, ranging in size from that of a grain of sand up to a small bean. From such sclerotia a Peziza form was obtained, which is shown, copied from Smith's figure, in *fig. 37*. The form was described by Berkeley and Wilson (**3b**) as a new species, under the name *Peziza postuma*. De Bary (**5**), however, to whom the material was sent, determined the fungus as *Sclerotinia Libertiana*. *Peziza postuma* is also given by Rehm (**10**, p. 816) as a synonym of *S. Libertiana*. In each of these cases the disease appears to have been caused by Botrytis or Sclerotinia alone, and no reason appears for claiming a connection between them.

CUCUMBER DISEASE.

BIBLIOGRAPHY.

1. HUMPHREY, J. E. Diseases of the cucumber plant. A sclerotium disease. Rept. Mass. Exp. Sta. **10**: 212. 1893.

2. COOKE, M. C. Cucumber diseases. Gard. Chron. III. **14**: 137. 1893.

The disease described by Humphrey (**1**) under the name of "timber rot" is not uncommon in cucumber houses in Massachusetts. The writer has met with it several times and also has received specimens from the New York Exp. Sta. at Geneva. Cooke (**2**) notes the occurrence of apparently the same trouble in England. The disease is characterized by a dry rot of the stem with a production of mycelium and sclerotia upon the surface. From the sclerotia *Sclerotinia Libertiana* readily develops. The writer has found no conidial form in connection with the disease. Humphrey, however, finding Botrytis on a decaying fruit, argues a connection between the forms. He obtained sclerotia in cultures from conidia which are stated to have shown complete identity in microscopic structure with sclerotia developed from the ascospores of the Sclerotinia. The form and manner of growth of the sclerotia were not the same, but this difference was ascribed to the nature of the substratum.

Humphrey's results have been repeatedly duplicated by the writer. It is true that Botrytis is often found on rotten cucumbers, and also that in cultures from conidia sclerotia may be

obtained indistinguishable in microscopic structure from those of *Sclerotinia Libertiana*. This has already been shown in connection with the lettuce disease. It was also shown there, however, that the form and manner of production of the sclerotia is highly characteristic and not affected by the substratum. There is, in short, no reason whatever for supposing, from this case, any connection between Botrytis and Sclerotinia except their occurrence in the same house. The entire distinctiveness of the two forms is nowhere more easily demonstrated than in such a case as this.

VEGETABLE, BULB, AND FRUIT ROTS.

BIBLIOGRAPHY.

1. COEMANS, M. E. Recherches sur la genèse et les métamorphoses de la *Peziza Sclerotiorum* Lib. Bull. de l'acad. roy. des sciences de Belgique II. **9**:62. 1860.
2. BREFELD, O. Untersuchungen die Fäulniss der Früchte betreffend. (Bot. Zeit. **34**: 28. 1876.)
3. WAKKER, J. H. (*a*) Vorläufige Mittheilungen über Hyacinthenkrankheiten. Bot. Centralb. **14**: 315. 1883.
   (*b*) Ueber die Infection der Nährpflanzen durch parasitische Peziza (Sclerotinia) Arten. Bot. Centralb. **29**: 309. 1887.
4. DE BARY, A. *loc. cit.*
5. KISSLING, E. Zur Biologie der *Botrytis cinerea*. Hedw. **28**: 227. 1889.
6. HALSTED, B. D. Fungous diseases of various crops. Rept. N. J. Agrl. Coll. Exp. Sta. **3**: 350. 1891.
7. MASSEE, G. (*a*) An onion disease. Gard. Chron. III. **16**: 160. 1894.
   (*b*) Onion Sclerotinia. Text-book of plant diseases 156.
8. POTTER, M. C. Rottenness of turnips and swedes in store. Journ. Board of Agr. **3**: 120. 1896.)
9. WEHMER, C. Untersuchungen über die Fäulniss der Früchte. (Zeitschr. f. Pflanzenkrankh. **6**: 173. 1896.)
10. OUDEMANS. Ned. Kruidk. Arch. II. **4**: 260.
11. SORAUER, P. Pflanzenkrankheiten.
12. FRANK, A. B. Die Pilzparasitären. Krankheiten der Pflanzen.

One of the most common cases of trouble caused by Botrytis and Sclerotinia is the rotting of various fruits, vegetables, etc. The writer has investigated a case of rotting of turnips found in Munich, Germany. Affected roots were not foul or badly decayed except in the worst affected portions, but showed

simply a slight discoloration and moist appearance of the flesh, no outward change appearing. No fungus was visible at first to the naked eye. When cut in two and kept moist over night a vigorous growth of *Botrytis cinerea* appeared on the affected parts, most abundant where worst affected and shading off toward the most recently affected portion, where no conidia developed. The interior was found to be filled with a vigorous mycelium similar to that in the lettuce and other diseases (*fig. 49*). Cultures on various media gave the usual Botrytis development, conidia being developed abundantly when badly affected tissue was used for infection, but very sparsely on newly affected portions or in cultures made therefrom. In the latter cultures sclerotia were quite numerous, being long, narrow, and thin, closely joined to the substratum in the characteristic Botrytis manner. It was found possible to infect sound roots with conidia by cutting out a plug, inserting the spores, and replacing the part cut out. There was no question that the rotting in this case was caused by *Botrytis cinerea*, pure and simple. The case described by Potter (**8**) is entirely similar. De Bary (**4**) and Coemans (**1**) found rotting of turnips, carrots, etc., caused by *Sclerotinia Libertiana* (*Peziza Sclerotiorum*). The writer has found by infecting turnips with Botrytis and Sclerotinia that an entirely similar effect is obtained and an intercellular mycelium produced which is quite indistinguishable. By making cultures, however, from the affected tissue, sclerotia are obtained, and in the one case conidia, which distinguish the two forms at once. This case, therefore, shows once more how easily confused these two forms are, having so similar a mycelium and effect, while at the same time it furnishes strong proof, when thoroughly looked into, of their entire distinctness.

Rotting of various fruits caused by Botrytis has been described by Brefeld (**2**) and Wehmer (**9**).

A rotting of onions is often caused by Botrytis and has been described by Halsted (**6**), Sorauer (**11**, p. 294), and Frank (**12**, p. 503). The writer found a similar case in Munich, where the affected tissue was permeated with a mycelium (*fig. 48*).

The Botrytis in this case was not a typical *cinerea*, having a low, dense manner of growth which persisted in cultures for many generations. The conidiophores were also short and stout (*figs. 5, 6*), and the conidia small and rather pointed as in **12**, plate 1. No sclerotia were found. Massee (**7**) ascribes the onion rot to *Sclerotinia bulborum* Wak. and figures (**7a**) a Botrytis apparently identical with *B. cinerea*, and a Peziza form showing no apparent distinction from *Sclerotinia Libertiana*. *Sclerotinia* (*Peziza*) *bulborum* was described by Wakker (**3**) as the cause of a hyacinth disease, a very interesting case in connection with the lettuce disease on account of its very similar mode of spreading and existence in the soil. No Botrytis stage was found, and Oudemans (**10**) states that none occurs. *Fig. 38* is copied from the latter. From all appearances it is doubtful whether the form described by Massee is the same as that of Wakker, and certainly the connection of the Botrytis and Sclerotinia forms, and their distinctness from the ordinary species, need further demonstration. An endless amount of confusion of these forms already exists on account of the multiplication of species for every new host.

III. Diseases caused by Botrytis alone.

No fungus is more common on dead or dying plant tissue than the common form of Botrytis. Not only is it abundant as a saprophyte, but cases often occur where it is a true parasite. Accounts of such cases are innumerable in botanical literature, but only a few can be briefly cited here. The species of Botrytis concerned has many different names, as has already appeared. In general it may be said that in Europe the ordinary form is referred to *B. cinerea* Pers., while in America the equally abundant species is usually called *B. vulgaris* Fr. These forms have been often regarded as identical, and the writer is able to state definitely that such is the case. Material from various parts of America and Europe has been carefully compared, both by examination and in cultures, from which it has been clearly shown that the forms are completely identical. On the basis of priority *cinerea* should be the specific name adopted, though, as

Wehmer[4] points out, *vulgaris* is more appropriate for so universal a species.

The following disease is a good type of this class:

A NEW DISEASE OF THE LINDEN.

In the spring of 1898, while working in Professor R. Hartig's laboratory at the University of Munich, the writer received several specimens of *Tilia parvifolia* which had been found in the nursery by Dr. von Tubeuf and appeared to be diseased. They were found among a considerable number of small saplings three to five feet high, growing close together in the usual nursery beds. At this time most of the trees were entirely leaved out, but these individuals had been noticed on account of their buds being not yet unfolded, though still green and apparently sound. The branches and upper part of the stem were also green and fresh, showing no abnormal symptoms, and the same was true of the roots. But in the lower part of the stem, from the surface of the ground up to a height of several inches, an abnormal condition was evident. Upon the surface of this part of the stem numerous excrescences were found, breaking out through the epidermis, with a thickness of about 0.5^{mm}, and varying greatly in shape and size. Some were nearly round, others irregular, and still others long and narrow, extending parallel with the stem, or more often around it. The latter form had a maximum length of about 2^{cm}, while the more circular ones had a diameter of 0.5^{cm}, or less. They had a dusty gray color and gave the stem an appearance somewhat like that of one affected with a Peridermium. *Text fig. 3* is from an excellent photograph of an affected stem, made by Dr. von Tubeuf. It was evident that the production of these excrescenses was proceeding from below upward, as the longest were just above the surface of the earth, while further up on the stem very small ones were just breaking out through the epidermis. In the affected part of the stem the wood and bark were discolored and evidently dead, but above and below it the tissue

[4] Zeitschr. f. Pflanzenkrankh. **4**: 209. 1894.

was still fresh and sound. The bark appeared to be first affected, as it was always discolored somewhat in advance of the wood. Upon examining the outward excrescences it was found that the dusty appearance of the surface was due to a dense growth of a form of Botrytis, much like *cinerea*, but not entirely agreeing with the typical form. The conidiophores were very stout and thick, averaging 20μ in diameter, and the conidia large and very various in shape, many being nearly 30μ in length (*fig. 10*). In cultures the form at once reverted to the typical *cinerea*, showing that it belonged to that species. Further examination showed that these excrescences were a sort of half-formed sclerotia, having the usual cellular structure at the base, but lacking a definite surface layer and resolving above into a dense mass of conidiophores. *Fig. 40* shows a section of one of these sclerotia. They originate in the cortical parenchyma, being separated by the bast layer from the wood. Besides these sclerotia the cortical parenchyma was found to be permeated by a vigorous mycelium about as in the other diseases described. The affected tissue was being rapidly destroyed, but the bast layer seemed to be little affected and no filaments could be found in the wood except a few in the most outer portion.

FIG. 3.—Linden stem attacked by Botrytis.

The affected portion of a stem was split in two and the two halves placed in a moist chamber. In one night a luxuriant Botrytis growth developed, being confined entirely to the cortex, most abundant in the worst affected portion and shading off gradually in the direction of what had been the upper part of the stem. Toward the boundary between the affected and unaffected areas no Botrytis appeared, but an abundant mycelium. In this portion, *i. e.*, the most newly affected, there appeared later ordinary black sclerotia having a long narrow form and located in the cortex, especially along the cut edges. The Botrytis gradually advanced, but was much more abundant back in the older part. Gelatine cultures were made with conidia and portions of the affected bark. The former produced a considerable mycelium, rather few conidia, and some sclerotia. The latter developed a similar mycelium, very few conidia, and numerous, larger, roundish sclerotia. Cultures were also made in the portions of the vegetative mycelium which appeared in the moist chamber upon the most newly affected portion of the stem (where no Botrytis appeared). This gave a vigorous mycelium with sclerotia, but no Botrytis. All of the sclerotia obtained from this material showed the characteristics of those of the botrytis type of the lettuce disease, being thin and joined with the substratum.

Several more affected trees were found in the nursery, both *Tilia parvifolia* and *T. grandifolia*. These showed the same symptoms as before. Some that were most affected seemed to be quite dead, and in the lower part of the stem the bark was quite destroyed, the wood being laid bare, but covered more or less with shreds of the bast which still remained. A few ordinary black sclerotia were found, but most were of the half-formed variety, covered with Botrytis. These appeared to have developed the previous fall, producing conidia in the spring.

The main features of this disease are these: a vigorous mycelium, starting apparently at the surface of the ground, proceeded upward through the cortical parenchyma, completely destroying it and eventually killing the plant. Sclerotia were developed upon the surface but reverted to the production of

conidia of *Botrytis cinerea* before becoming mature. This may have been due to the coming on of winter before the sclerotia were fully formed; at any rate the fungus was able to develop sclerotia and conidia in the usual manner, as shown in cultures and the moist chamber. It is believed that this disease was caused solely and primarily by *Botrytis cinerea*, in this case a true parasite. Cultures and observations showed throughout the same characteristics as found in Botrytis in connection with the lettuce disease and there is no reason to suppose that any other species was involved. This interesting disease upon the linden appears to be an entirely new one, and is the first of this class to be reported upon a woody plant. Its similarity, however, to some of the other stem rots herein described is apparent.

BOTRYTIS ON ROSE TWIGS.

Some twigs of hothouse roses were obtained in Munich by the writer, which were affected by a dying away of the tips, the disease gradually extending down the stem. The extreme tips were entirely dead and covered with a Botrytis growth. Further down the stems were turning black and dying, but no Botrytis was visible. Sections showed that the interior of affected parts of the stem was full of filaments. In the worst affected parts the whole tissue was destroyed and Botrytis conidiophores were growing out through the surface. In the less affected parts it was found that the disease advanced by large filaments which grew at first through the area of bast fibers, entirely disorganizing this tissue before the rest was at all affected. Later the whole stem became included. *Figs. 46* and *47* show cross and horizontal sections of affected twigs with the filaments among the bast fibers. It appeared in this case, as in several others already described, that the most actively parasitic filaments which attack new tissue bear no conidia, the latter appearing later on the older parts. The species was the usual *cinerea* but was especially luxuriant, bearing large, many-branched conidiophores. No sclerotia were found upon the limited material at

hand, but cultures from the Botrytis gave at first conidia and later sclerotia of the usual botrytis type.

Among the many other diseases of this class which have been described, space only permits that the following be mentioned:

CONIFERS.

TUBEUF, K. F. von. Bot. Centralb. **33**: 347. 1888. Also: Beiträge zur Kenntniss der Baumkrankheiten. Pflanzenkrankheiten 283.
BEHRENS, J. Zeitschr. f. Pflanzenkrankh. **5**: 136. 1895.
RITZEMA BOS, J. Forstlich-naturwiss. Zeitschr. **6**: 174. 1897.
MASSEE, G. Text-book of plant diseases 160.

GRAPE.

MÜLLER-THURGAU, H. Landwirtsch. Jahrb. **17**: 83. 1888.
VIALA, P. Rev. gén. de bot. **3**: 145. 1891. (Zeitschr. f. Pflanzenkrankh. **7**: 159. 1897.)
RAVAZ, L. Compt. rend. **118**: 1289. 1894. (Zeitschr. f. Pflanzenkrankh. **5**: 49. 1895.)
CUBONI, G. Bull. di Notizie Agrarie. **2**: 487. 1896. (Zeitsch. f. Pflanzenkrankh. **7**: 159. 1897.)
VON BABO UND MACH. Weinbau.

LILY.

WARD, H. M. Ann. Bot. **2**: 319. 1888. Diseases of plants 117.
KEAN, A. J. Bot. Gaz. **15**: 8. 1890.
MASSEE, G. Text-book of plant diseases. 161.

HORSE CHESTNUT.

KISSLING, E. *Loc. cit.*

PRUNUS TRILOBA.

TUBEUF, K. F. VON. Pflanzenkrankheiten 281.

GENTIAN.

KISSLING, E. *Loc. cit.*
PRILLIEUX ET DELACROIX. Bull. Soc. Myc. de France **6**: 135. 1890.

CYCLAMEN AND PRIMULA.

WEHMER, C. *Loc. cit.*

In all these cases the general nature of the disease was the same, Botrytis appearing more or less on affected parts and often forming sclerotia. Many interesting points are brought out in some of the descriptions, but they have little bearing on the question under consideration. It may be mentioned that the

Botrytis Douglasii of Tubeuf is without any doubt a form of *B. cinerea*, as the writer has ascertained by examination of the original material in cooperation with Dr. von Tubeuf. In Professor Ward's lily disease the species was thought to be distinct from *cinerea* on account of the large size of the conidia (20–25 × 15μ). The writer has often found the ordinary species with spores as large as 30–15μ, however, and it would seem from Professor Ward's figures of the conidiophores that the form must be very close to *cinerea*. In some of these cases, notably that of the grape, the Botrytis is referred to *Sclerotinia Fuckeliana* De By., its supposed Peziza form, which is said to develop from sclerotia on affected grapes. This form is unknown to the writer, but has been held by De Bary to be the real mature form of *Botrytis cinerea*. Pirotta (N. Giorn. Bot. Ital. **13**: 130. 1881) has also described *Fuckeliana* as distinct from *Libertiana*, but it is apparent in almost all cases where *B. cinerea* is referred to as *Scl. Fuckeliana* that nothing more was observed than the ordinary conidial form and possibly sclerotia. Whether or not this is the true perfect form of *cinerea*, it is certain that the connection has never been proved directly, and much has been taken for granted by various writers upon no foundation whatever.

IV. Diseases caused by Sclerotinia Libertiana alone.

Cases are not rare of *Sclerotinia Libertiana* attacking plants when no Botrytis appeared. The cucumber disease already described is really one of this sort, as the Botrytis simply happened to occur in the same house. The writer has seen water cress and parsley in greenhouses attacked by this species, such cases being not uncommon in the Boston houses where these plants are considerably grown. Tomatoes also occasionally show the same trouble, rotting at the surface of the ground. The Peziza form is occasionally found developing from sclerotia in the soil in such houses.

De Bary (*loc. cit.*) describes a stem rot of Zinnia, Petunia, and other plants caused by this species. It is also not uncommon upon Helianthus. Dr. O. Kirchner, of Hohenheim, gave

the writer Peziza-bearing sclerotia from such a disease of this plant. Pammel (Trans. St. Louis Acad. **6**: 191. 1893) has described a similar disease. W. G. Smith (Gard. Chron. III. **8**: 324. 1890 and III. **9**: 791 1891) describes a stem rot of hollyhocks caused by *Scl. Libertiana*. The disease was entirely similar in all these cases and needs no extended description. The stem of affected plants rotted just above the ground, being filled with a vigorous mycelium as in the diseases already described. Sclerotia were produced both upon the surface and in the interior cavity of the stem, from which the Peziza form readily developed.

A disease of clover has been described by several writers which is very similar to those under consideration but ascribed to *Sclerotinia Trifoliorum* Erik. which is regarded as distinct from *Libertiana* though apparently very similar. The writer received alfalfa plants from Mr. F. C. Stewart of the New York Exp. Station which were supposed to be affected with this species. The sclerotia, however (*text fig. 1 e*), both from diseased stems and cultures, were entirely similar to those of *Libertiana*, and produced a Peziza form which left no doubt that it was that species.

V. General conclusions on Sclerotinia Libertiana and Botrytis cinerea.

During the four years in which this work has been carried on a great deal has been done which has no special connection with that part of the subject with which the present article deals. A large amount of material has been obtained and the fungi grown and studied under all sorts of conditions. Most of the results which it is intended to emphasize here have already been brought out in various places in this description. It is maintained above all *that Sclerotinia Libertiana and Botrytis cinerea have no connection whatsoever with each other, and that the former species has no conidial stage of this type*. Growing either as a saprophyte or parasite, it shows at all times a mycelium composed of large, branching, septate filaments, averaging about 10–15 μ in diameter, which produce

organs of attachment abundantly when in contact with any hard substance. Sclerotia are always produced abundantly in cultures and upon affected plants. These vary in size up to an inch in length, having an irregular form, but are solid and "meaty" and produced embedded in the mycelium, having no connection whatever with the substratum. The Peziza form is readily obtained from them. The internal structure of these sclerotia consists of a mass of thickened filaments knotted closely together and surrounded by a black, cellular layer. This species is a typical example of a facultative parasite, being able to exist indefinitely as a saprophyte but at the same time capable of attacking a great variety of plants in a strictly parasitic manner.

Botrytis cinerea is without doubt a closely related species, and has many points of resemblance. It is not as strongly parasitic as the other species, attacking living plants more commonly only when they are under unfavorable conditions or when injured in some way. At times, however, it appears to be a true parasite. When growing as a saprophyte it has no particular resemblance to *Scl. Libertiana* under the same conditions, producing much less mycelium and a great abundance of conidia. When growing as a parasite it is in some respects indistinguishable from the other species. The mycelium is entirely similar and organs of attachment are produced which are likewise exactly the same. The effect upon the plant is often entirely similar. As a parasite it appears to produce fewer conidia in proportion to the degree of parasitism. Often in newly affected tissue none appear. Sclerotia are often produced in cultures and on affected plants but with considerable uncertainty. Not rarely cultures made from conidia produce no spores whatever, but numerous sclerotia. This is most common when parasitic material is used. The sclerotia are highly characteristic and suffice at all times to distinguish this species from the other. They usually have a narrow form, especially in tube cultures, and are always thin and inseparably attached to the substratum, lacking entirely the definite form and the solid, "meaty" structure of the sclerotia of *Scl. Libertiana.* So far as known no Peziza has ever

been obtained from sclerotia developed from *Botrytis*. On the basis of internal structure these sclerotia cannot be clearly distinguished from the others. They vary in compactness and seem to have no very characteristic makeup. The two species often occur together, as Botrytis does in connection with many other fungi, and it is believed that the only unprejudiced argument which has ever existed in favor of the connection between *Sclerotinia Libertiana* and *Botrytis cinerea* is their frequent simultaneous occurrence, in connection with the similarity of the mycelium and the fact that they often attack plants in a very similar manner; all of which is explained by their close relationship. When carried further than this they may be readily separated and distinguished from one another and the distinctive characters brought out which have been described.

MASS. AGRIC. COLLEGE,
Amherst, Mass.

EXPLANATION OF PLATES XXV–XXVII.

PLATE XXV.

FIG. 1. Typical conidiophore of *Botrytis cinerea* Pers.

FIG. 2. Portion of same, more enlarged.

FIG. 3. Conidiophore from old, exhausted culture.

FIG. 4. Botrytis slightly enlarged.

FIGS. 5–9. Botrytis from onion.

FIGS. 10–11. Conidia of *Botrytis cinerea*.

FIG. 12. Conidia of Botrytis from onion.

FIGS. 13–17. Development of conidiophore of *Botrytis cinerea* from mycelium within a plant.

FIG. 18. Development of terminal branches.

FIGS. 19–22. Forms of organs of attachment.

PLATE XXVI.

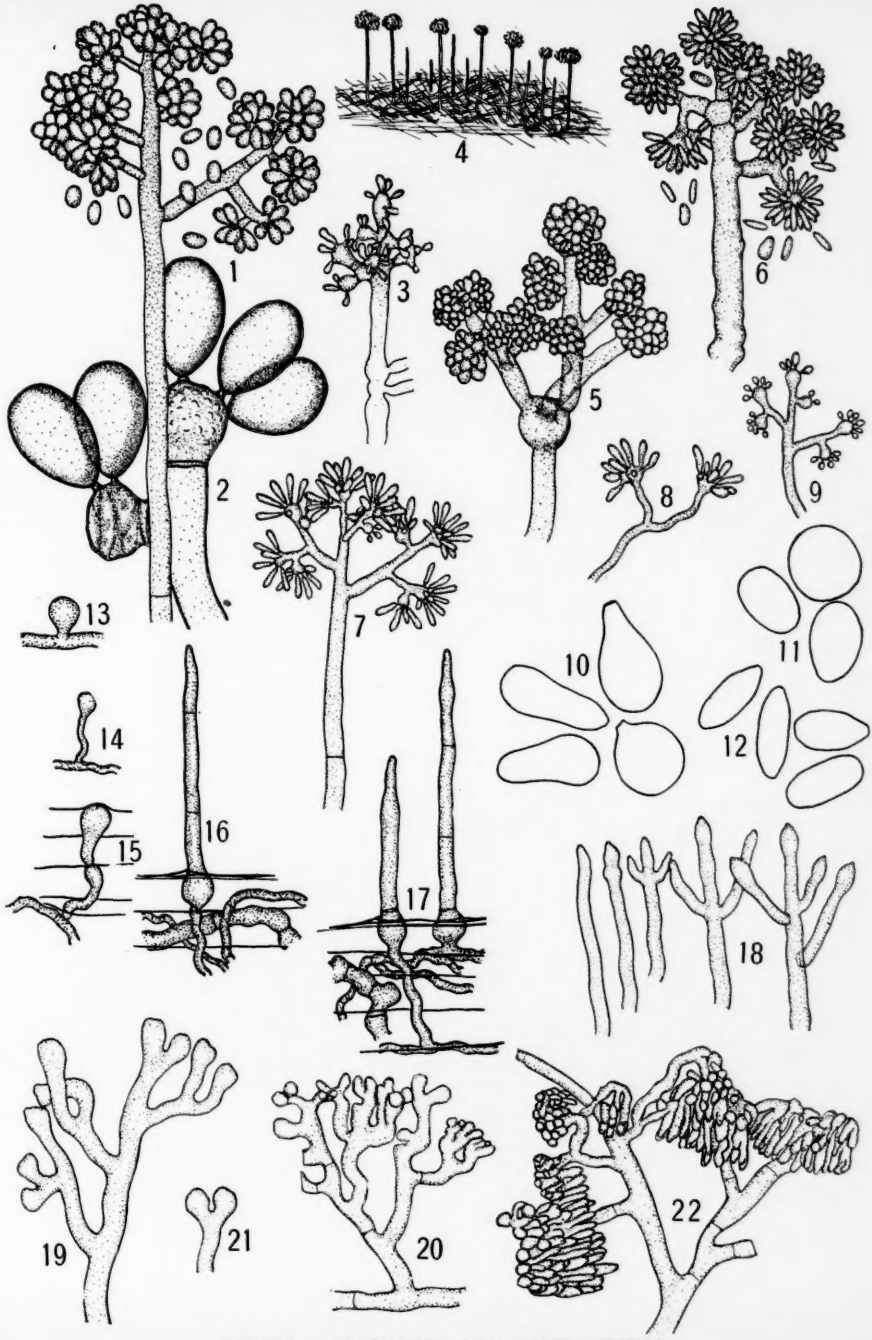
FIGS. 23–25. Forms of organs of attachment.

FIG. 26. Tip of a branch of an organ of attachment growing against glass.

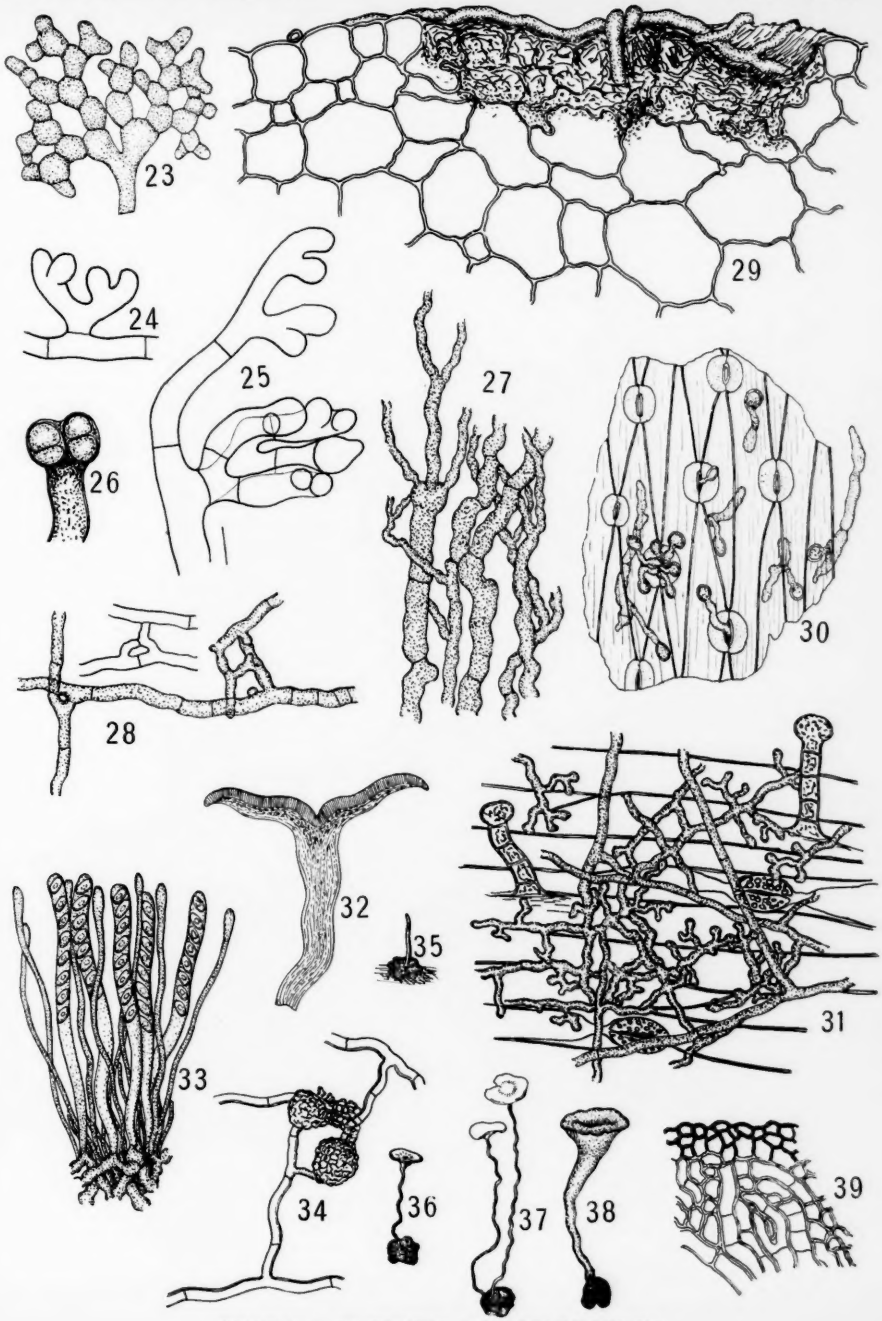
FIG. 27. Mycelium of Botrytis from stem of lettuce seedling, causing "damping off."

FIG. 28. Cross connections in Botrytis mycelium.

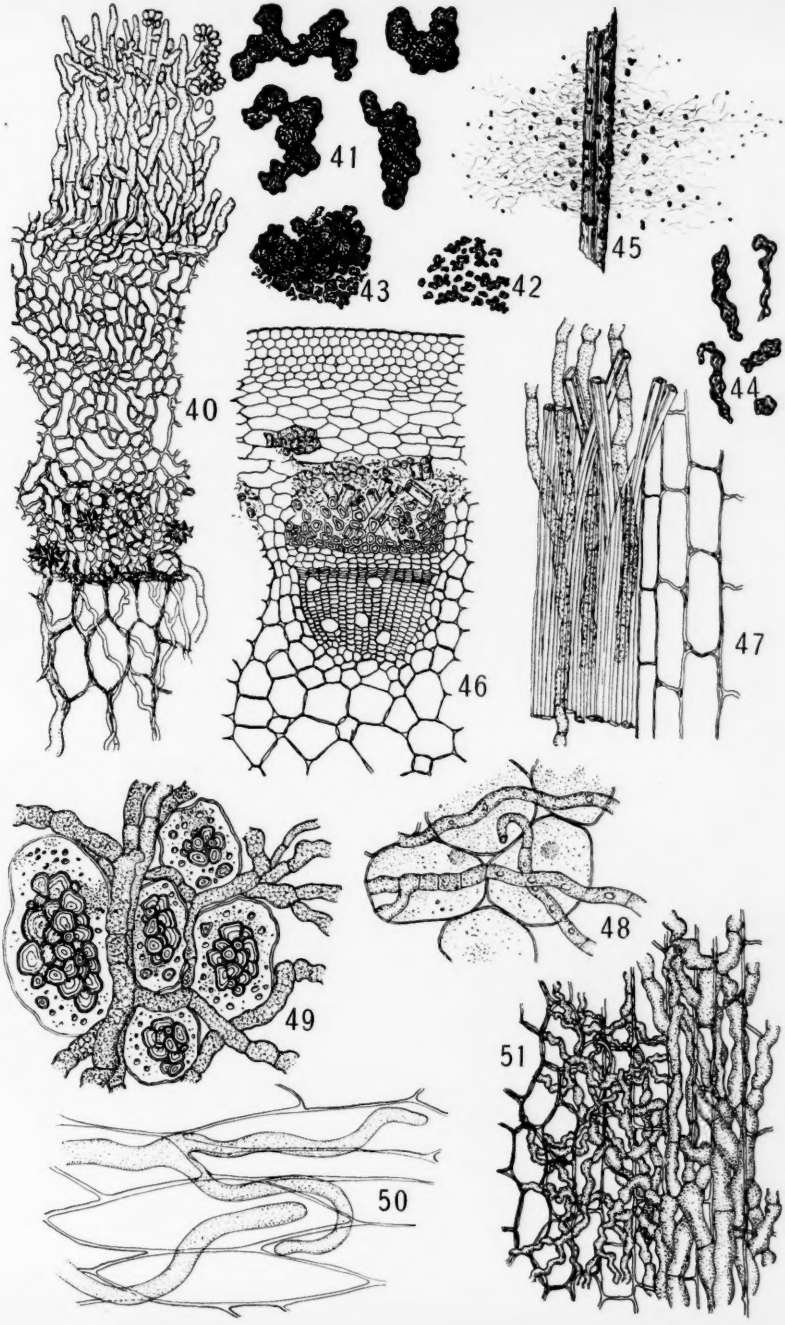
FIG. 29. Filaments of *Sclerotinia Libertiana* Fckl., entering lettuce leaf.



SMITH on BOTRYTIS AND SCLEROTINIA



SMITH on BOTRYTIS AND SCLEROTINIA



SMITH on BOTRYTIS AND SCLEROTINIA

FIG. 30. Conidia of *Botrytis cinerea* germinating on and entering epidermis of an onion leaf.

FIG. 31. Mycelium of *Scl. Libertiana*, with organs of attachment on surface of lettuce leaf.

FIG. 32. Longitudinal section of Peziza fructification of *Scl. Libertiana*.

FIG. 33. Asci and paraphyses of same, more enlarged.

FIG. 34. Commencement of formation of a sclerotium.

FIG. 35. Peziza stalk arising from a sclerotium.

FIG. 36. Mature Peziza form.

FIG. 37. *Peziza postuma* B. & W. (Copied from Smith.)

FIG. 38. *Sclerotinia* (*Peziza*) *bulborum* Wak. (Copied from Oudemans.)

FIG. 39. Cross section of sclerotium.

PLATE XXVII.

FIG. 40. Section of Botrytis sclerotium from linden.

FIG. 41. Typical sclerotia of *Sclerotinia Libertiana*.

FIG. 42. Small sclerotia from lettuce.

FIG. 43. Sclerotial crust formed by lettuce fungus.

FIG. 44. Sclerotia of *Botrytis cinerea*.

FIG. 45. Formation of secondary sclerotia.

FIG. 46. Cross section of rose twig, showing Botrytis filaments in the bast.

FIG. 47. Longitudinal section of same.

FIG. 48. Botrytis filaments in onion.

FIG. 49. Botrytis (or Sclerotinia) filaments in turnip.

FIG. 50. Sclerotinia (or Botrytis) filaments in lettuce leaf, advancing into sound tissue.

FIG. 51. Sclerotinia (or Botrytis) filaments in badly affected lettuce stem.

A CONTRIBUTION TO THE LIFE HISTORY OF QUERCUS.

CONTRIBUTION FROM THE HULL BOTANICAL LABORATORY. XIX.

ABRAM H. CONRAD.

(WITH PLATES XXVIII AND XXIX)

THE material for this study was all collected in the vicinity of the University of Chicago in the spring and summer of 1898. Gatherings of several species were incidentally made, but *Quercus velutina* Lam. (*Q. coccinea tinctoria* Gray) afforded the most complete series, and as my investigations have been devoted chiefly to this species, it is alone considered in this paper.

In dealing with material so refractory as Quercus one seldom secures a satisfactory series during a single season of collecting. The difficulties to which I here refer are due in part to the stubbornness with which the material resists the penetration of fixing agents, and in part to the remarkable uniformity with which any stage occurs in all the ovules at the same time. This bars one from an opportunity of retrieving any loss from the mismanagement of a batch of material. Detailed cytological observation has not been attempted, the object having been rather to determine the nature, order, and time of events as they occur in the gametophyte generation.

Except the brief account of Quercus by Miss Benson in her work on the Amentaceæ, I have no knowledge of any attempt to work out the life history of the genus.

The work was done under the guidance and encouragement of Dr. John M. Coulter and Dr. Charles J. Chamberlain, to whom my thanks are due.

MATERIAL AND TECHNIQUE.

During late winter and early spring collections were made at intervals of several days, with a view to determine the stage of

development in which the several structures pass the winter, and the sequence of their development as it occurs in the spring. Beginning with May 5 and continuing to July 7, gatherings were made at intervals of two or three days, and in order that the material might be typical it was mostly taken from the upper branches of a single thrifty tree.

Owing to the protective covering of scales and glandular hairs which prevented the penetration of fixing and imbedding agents, great care was exercised in removing this so as to expose freely the structures to be investigated. Several fixing agents were tried, but chromo-acetic and picro-acetic were most satisfactory. The chromic agent preserved the material well, but rendered it more brittle and difficult to section. The picric agent is to be preferred. The chromo-acetic was a 1 per cent. aqueous solution of chromic acid with $\frac{1}{2}$ per cent. acetic acid. The picro-acetic was a saturated solution of picric acid in 70 per cent. alcohol with 0.5 per cent. acetic acid. The chromic fluid proved best when the material was wet in 95 per cent. alcohol, and quickly passed into the fixing agent. The picric was most satisfactory when used at a temperature of 80 to 90 degrees Centigrade.

Thus fixed, the material was dehydrated with successive grades of alcohol, passed into xylol, imbedded in paraffin, cut in serial sections 5 and 10 μ in thickness, and stained upon the slide. Several stains were tried. Cyanin and erythrosin proved good for early stages, Delafield's haematoxylin for archesporial stage, and fuchsin and iodine green for embryo-sac and embryo.

THE STAMENS AND POLLEN.

Material collected in early spring (March 7) may be taken as fairly representing the stage of development in which the microsporophylls pass the winter. While the structure is well differentiated into filament and anther, the latter consists of a mass of apparently uniform cells (*figs. 1, 2*). Upon the approach of a growing temperature there occurs a rapid development and a corresponding early differentiation into the usual regions of

sporogenous, tapetal, and wall tissues, the latter comprising two to four layers of cells (*fig. 3*). These groups of cells exhibit nothing unusual either in their development or destiny. The inner wall cells are the first to break down, contributing their substance to the cells within and leaving the tapetum to form a sheath which incloses and nourishes the sporogenous cells. Before the final disintegration the cells of the tapetum show numerous prominent nucleoli, and quite generally become binucleate. The two nuclei are plano-convex or concavo-convex, with their plane or concave surfaces facing each other (*fig. 6*).

The spore mother-cells increase in size, separate, and form the usual tetrads (*fig. 4*). The mature spore has a smooth surface, is somewhat angular, and has a diameter of about 30 μ. The exospore has three points of weakness, which seem to correspond to the three exterior angles of the tetrad, and which afford points of easy rupture to the tube in germination. At the time the spores are discharged, a small proportion of them show that the division into the tube and generative nuclei has occurred, the latter being the smaller and lenticular in form. Each contains a single prominent nucleolus (*fig. 5*). The subsequent history of the microspore was not satisfactorily traced. The difficulties of following it through the interval of thirteen months intervening between pollination and fertilization are multiplied by a copious development of nucleated hairs which takes place in the loculus during the interval. Three attempts were made at artificial germination of the pollen but without success. In 1898 the pollen of *Q. velutina* was shed May 17 and 18 in the vicinity of Chicago.

THE OVULE.

The first indication of an ovule is manifest after the renewal of growth following a period of about eleven months of arrested ovarian development. *Fig. 7* represents a transverse section of the ovary on the date of March 7, and shows the condition attained during the first year of growth. The three carpels are so fused as to form three nearly distinct loculi. These communicate with one another at the base, but in the middle and

upper regions they are separated by the complete fusion of the carpels. Each loculus contains two prominent placental folds (*fig.* 7, *hh*), and numerous hairs developing from the inner surface of the carpel. *Fig.* 9 is a longitudinal section through a carpel from material collected April 21. *Fig.* 10 is a transverse section through the placental folds, which mark what may be regarded as the beginning of ovular development.

Material collected May 5 shows the first indication of the integuments (*fig.* 11, *ee*). The nucellus now rapidly elongates by active cell growth and division, especially in the basal region. The integuments push forward at a still more rapid pace, and in a short time completely inclose the nucellus. In the meantime, growth being more active in the outer angle of the base of the ovule, it is forced to an erect position.

ARCHESPORIUM.

About the time the nucellus is fairly inclosed by the integuments there is a mass of from twenty to sixty or more cells in its upper half which clearly manifests an archesporial character. This character is manifested by a larger and clearer nucleus, a coarser linin net work, and larger granules, in contrast with the nuclei of the surrounding cells, while the cytoplasm takes a much deeper stain with Delafield's heamatoxylin. In *figs.* 14–20 the extent and position of this archesporial mass is indicated. Many ovules showing this stage were sectioned and figures could be indefinitely multiplied.

In view of the usual record of events as they occur in the development of megaspore in angiosperms this archesporial mass is marked by two striking peculiarities: (1) its unusual abundance, and (2) the cells are potential megaspores as is proved by subsequent events. While multiple megaspores are known to occur in *Rosa livida*, and some of the Amentiferæ, Ranunculaceæ, Rubiceæ, and a few others, Casuarina is probably the only case hitherto known which strikingly resembles Quercus in this regard.

This archesporial stage is of relatively long duration, apparently a period devoted to the accumulation of energy to be

expended in the important changes which follow in rapid succession.

EMBRYO-SAC.

At length certain cells centrally located in this archesporial mass indicate by a thickening of the linin network, enlargement of the granules, and a coarser appearance of the nucleus, that they are entering the prophase of mitosis. The nucleoli of such cells contrast with those of neighboring cells in size and staining qualities.

Before the spirem is formed the race is usually yielded to a single vigorous cell, apparently the fourth or fifth below the surface. This cell, improving the advantage thus accorded, crowds upon its sister cells, and they in turn may soon show evidence of collapse. *Figs. 21* and *22* show a condition not uncommon, in which some of the adjacent cells are in advanced stage of deterioration, while in other instances the neighboring cells show little evidence of breaking down when the spirem is formed in the fertile megaspore (*figs. 24, 25*). It is not unusual to find the condition represented in *fig. 23*, in which the nuclei of cells in the apical region of the nucellus, previous to the spirem stage of the fertile megaspore, contain numerous small nucleoli, presumably the fragments of a single large nucleolus common to all healthy cells, and whose fragmentation may be regarded as an early evidence of the deterioration of the cell.

Inasmuch as these more marked cells usually bear a lineal relation to each other, it might suggest the usual type of tapetal cells, potential and fertile megaspores recorded for angiosperms. The events leading to this condition, and those that follow, preclude this hypothesis; and in addition it may be said that the axial position does not always obtain. Such cells may lie side by side, or they may be separated by one or more intervening cells.

As stated above, it is usual that but a single archesporial cell proceeds so far as to form the spirem. It is, however, not always the case. *Fig. 29* shows a well-defined exception. It shows two well-formed spindles with the chromosomes arranged

upon the equatorial plane. The number and form of the chromosomes are so markedly different from those of the vegetative cell that they afford conclusive evidence that the divisions are of the reduction type, and in view of all the circumstances it can scarcely be doubted that it is the first division in fertile megaspores. In *fig. 31* we have a case in which two adjacent megaspores have reached the four-celled stage. Considering the large number of archesporial cells, and the frequency with which a number of these undergo early mitotic phases, it has been a matter of surprise that the phenomenon of a two-celled stage or a four-celled stage in more than one megaspore in the same nucellus does not more frequently occur. This condition, however, we may better appreciate when we have learned more of the causes which determine the fate of a cell.

The first division observed in the apical region of any mature nucellus is shown in *figs. 26* and *27*. This is believed to be the spirem stage of the first division of the megaspore. The thread is small and I am unable to determine whether or not it conforms to the mode of splitting commonly ascribed to spore mother cells. Whatever weight, however, may be attached to synapsis as restricted to such division obtains here. Material collected June 4 and 5 afforded many cases of the fertile megaspore presenting phases illustrated in *figs. 21–27*. The transition to the four-celled stage of the embryo sac is accomplished with speed and marked uniformity of time in all the ovules. Material collected June 5 showed early phases up to and including the spirem stage of the first division of the megaspore to be quite common (*figs. 21–25*), while material collected two days later showed the four-celled stage of the sac with corresponding frequency.

Notwithstanding a large number of ovules in which the two-celled stage might be sought were sectioned, *fig. 28* probably illustrates the most satisfactory case of a two-nucleated sac. It shows two deeply stained masses which I take to be the two unorganized daughter nuclei of the first division of the megaspore, and in no case did I find two nuclei in the so-called resting stage.

In view of all the evidence, I cannot escape the conviction that the first division that occurs in the archesporium of the mature nucellus is quickly followed by a second division without the previous reorganization of the nuclei of the first division, and that this results in the four-nucleated embryo sac.

Not only does the space of two days seem sufficient for the transition from the one-celled to the four-celled stage, but in some instances development had exceeded this. It was in material collected June 7 that I found the most satisfactory illustration of the eight nuclei of the sac (*fig. 32*). Here the synergids and oosphere are in the micropylar region, the three antipodals in the base of the sac, and the polar nuclei in the act of fusing in the middle region. In this instance I find no evidence that the pollen tube has made its approach, yet in view of its elusive character it would be unsafe to affirm that it has not done so. Several cases of the fusion of the polar nuclei were observed, but the presence of the antipodals was usually a matter of doubt. This, however, is to be expected, when we consider the usual ephemeral nature of these cells, and since their nuclei possess no character which distinguishes them from the nuclei of the disintegrating cells of the nucellus, it is not an easy matter to identify them.

About the time the four-celled stage is reached, the embryo-sac begins to enlarge rapidly at the expense of the nucellar tissue, and by the time of the fusion of the polar nuclei, or soon after, the nucellus has almost entirely broken down. There is usually a fragment of the nucellus extending from the chalazal region a short distance up one side. This gives to the embryo-sac a somewhat pointed base, which is the only structure observed suggestive of the so-called *caecum*.

The synergids crowd well up into the micropyle, and display that striated beaked structure noted by observers in some other plants. *Fig. 34* in no way exaggerates the prominence of these striated tips, and, as Chamberlain observed in Salix, these tips may persist for a considerable time as a plug in the micropylar end of the sac.

The course of the pollen tube in relation to the synergids I have been unable to determine. In the most positive case of a pollen tube within the embryo-sac the course seems to have been between the synergids and the wall. Many cases were found of an open micropyle strewn with mucilaginous residue, indicating that the tube had passed, but a most careful search failed to reveal its presence within the sac. It is not unusual to find in the micropylar region of the sac numerous refractive starch granules, suggestive of the rupture of the tube and the discharge of the male cell, but the fusion with the nucleus of the oosphere was not observed.

ENDOSPERM.

There is a very early and copious development of endosperm. I have no proof that this begins before the fusion of the male cell with the oosphere, yet its universally prompt appearance when the sac reaches maturity seems to me to indicate a doubtful time relation. This early appearance of endosperm is a source of perplexity in the investigation of male cells and antipodals. The nuclei of the endosperm lie free in the stratum of protoplasm about the wall of the embryo-sac, and the cells show no evidence of running in walls up to the time at which the embryo cuts off cells to form the dermatogen. *Fig. 36* shows the condition of the endosperm as it occurs in connection with the embryo illustrated in *fig. 39*.

EMBRYO.

The embryo is anchored to the endosperm in the micropylar region by a short but distinct suspensor. The suspensor, at first a single cell, divides once by a vertical wall after the first few divisions have occurred in the embryo. *Fig. 37* shows the embryo of four cells while the suspensor is still undivided. At some time after this, and probably about the time the embryo cuts off cells to form the dermatogen, the vertical division occurs (*figs. 37–39*).

SUMMARY.

1. Winter buds show the stamens well formed, but with no perceptible differentiation of the cells of the anther. The carpels are also evident but relatively more rudimentary.

2. With the early growing conditions of spring there occurs the usual differentiation of the anther into sporogenous, tapetal, and wall cells. The sporogenous cells separate and form tetrads in the usual manner. The inner wall cells are the first to break down. The tapetal cells form a sheath about the spores, become binucleate, and break down shortly before the spore reaches maturity. A relatively small proportion of the spores show the division into generative and tube nuclei while still in the anther.

3. During the first year the carpels fuse so as to form three nearly distinct loculi each with two placental folds, upon each of which a single ovule develops, but the first indication of an ovule appears some time after the renewal of growth the following spring.

4. About the time the nucellus is inclosed by the integuments there is manifest in its upper half a mass of from twenty to sixty or more cells of distinct archesporial character. This character is evidenced by a larger and clearer nucleus with coarser linin network and larger granules, and by the cytoplasm of the cell taking a deeper stain than that of neighboring cells.

5. At length certain cells in the archesporial mass show a tendency to develop into megaspores. The race is usually yielded to a single cell which develops directly into the megaspore, the second division quickly following the first without the previous reorganization of the daughter nuclei of the first division.

6. Occasionally more than one cell in the same nucellus reaches the four-nucleate stage of the embryo-sac.

7. The mature embryo-sac contains the usual two groups of four nuclei each. There occurs an early fusion of the polar nuclei, followed by a copious development of endosperm which shows no tendency to run in walls up to the time when the embryo is well differentiated.

8. The first division of the oospore is transverse, and the suspensor undergoes but one subsequent division, which is vertical.

ENGLISH HIGH AND MANUAL TRAINING SCHOOL,
Chicago.

EXPLANATION OF PLATES XXVIII–XXIX.

The figures are reduced from drawings traced by means of a Bausch and Lomb camera. Nos. 1, 9, 12, 13 were made with Reichert objective no. 7; the others with a Spencer or a Bausch and Lomb $\frac{1}{12}$ oil immersion with ocular combination magnifying 1200 and 1300 diameters.

FIG. 1. Longitudinal section through two stamens showing winter stage.

FIG. 2. Section of an anther, same date as above, showing cells of uniform character, more highly magnified.

FIG. 3. Section of anther of date April 22; shows differentiation into wall, tapetal, and sporogenous regions; the inner wall cells showing evidence of collapse.

FIG. 4. The formation of tetrads from the pollen mother cell.

FIG. 5. The mature spore with generative and tube nuclei.

FIG. 6. Two tapetal cells showing the binucleate and multinucleolate condition preceding final disintegration.

FIG. 7. Transverse section of the ovary showing loculi and placental folds (*hh*); March 7.

FIG. 8. A section of the placental fold more highly magnified; March 7.

FIG. 9. Longitudinal section of a carpel; marks the beginning of the ovule and the development of hairs from the inner surface of the carpel; April 21.

FIG. 10. Transverse section of the placental fold; April 21.

FIG. 11. Section of the ovule showing the first indication of the integuments (*ee*); May 5.

FIG. 12. Outline of the transverse section of the ovary showing the three loculi each containing two ovules; one loculus shows the hairs with which the cavity becomes almost completely filled; the ovules, nearly enclosed by the integuments, have assumed a position almost at right angles to the plane of the section.

FIG. 13. Outline of the section of the nucellus with its integuments; date same as *fig. 12*.

FIGS. 14–20. Longitudinal section of the nucellus showing the extent and position of the archesporial cells; dates ranging from May 13 to May 22; *fig. 20* is a section almost at right angles to the long axis of the nucellus.

FIG. 21. A row of five cells showing a tendency to develop into megaspores; the middle cell has taken the lead and the cells immediately above and below are breaking down.

FIGS. 22–25. Early prophases of mitosis in the first division of the megaspore.

FIGS. 26–27. Spirem stage of the first division of the megaspore.

FIG. 28. The unorganized daughter nuclei of the first division of the megaspore.

FIG. 29. Two megaspores in the same nucellus in act of first division, showing symmetrical spindles, with short and dense chromosomes arranged upon the equatorial plane, suggestive of reduction division.

FIG. 30. Four-celled stage of embryo sac; June 10.

FIG. 31. Two embryo-sacs in the same nucellus in the four-celled stage.

FIG. 32. Embryo-sac with the usual eight cells; shows the fusion of the polar nuclei in the middle portion of the sac.

FIG. 33. Embryo-sac with two synergids and oosphere in the micropylar region, and the polar nuclei in the act of fusion.

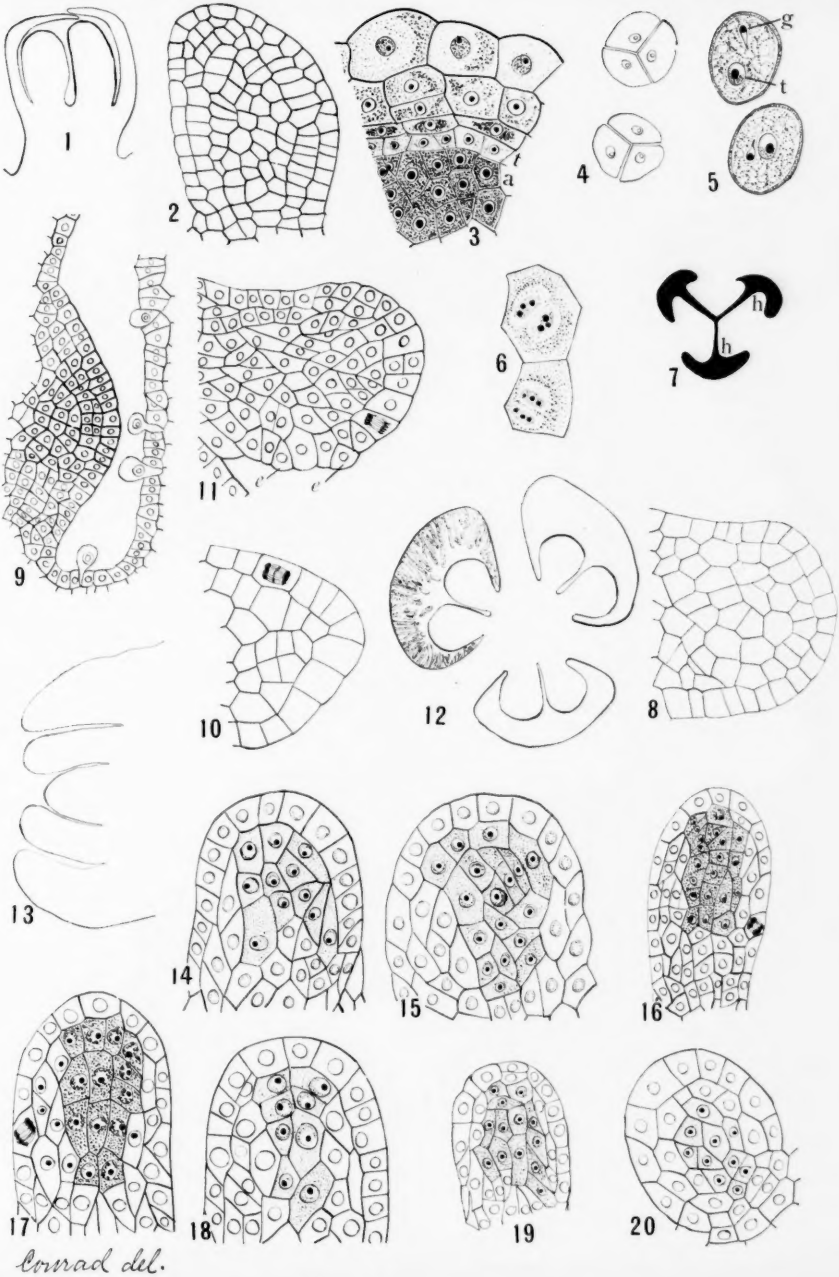
FIG. 34. Synergids with prominent striated beaks crowding into the micropyle.

FIG. 35. Synergids in the micropylar end of the sac and the oosphere suspended below.

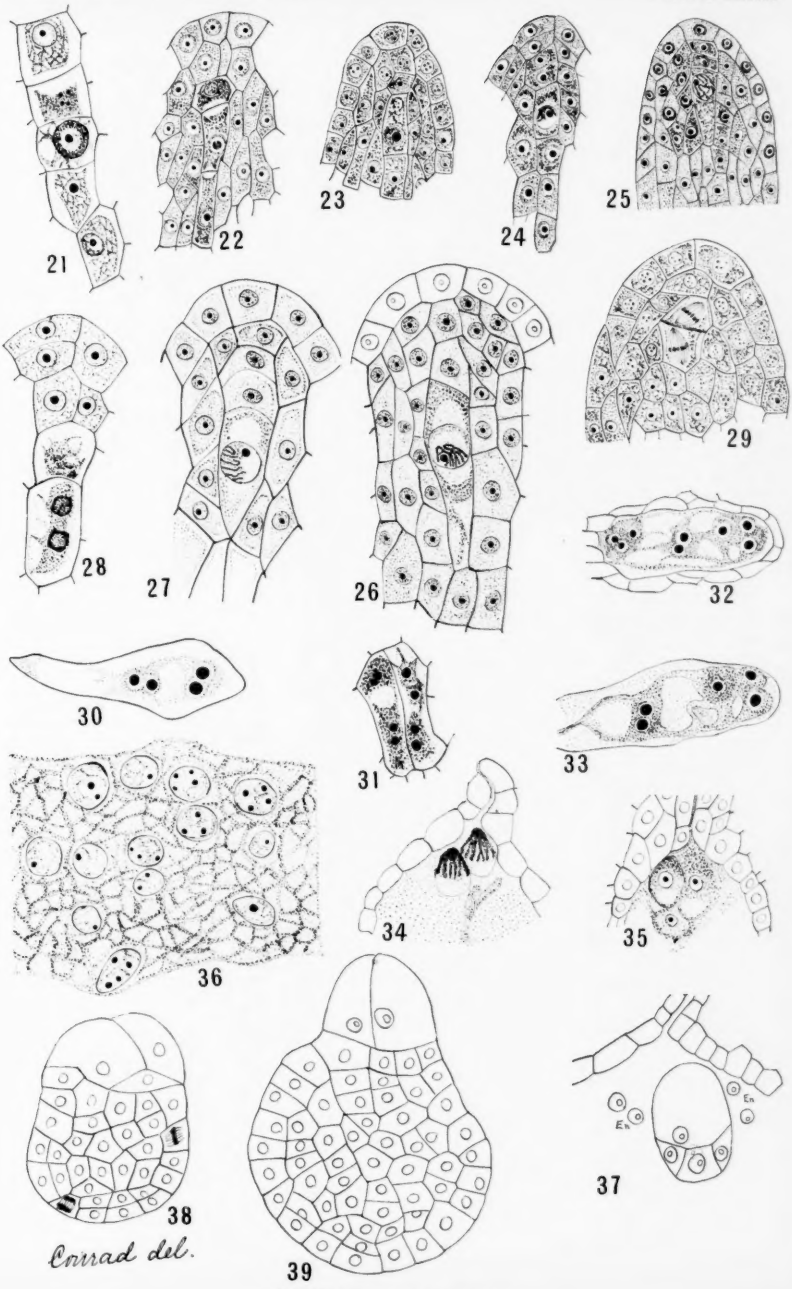
FIG. 36. Endosperm showing the absence of any tendency to form walls at the time of embryo development represented in *figs. 38–39*.

FIG. 37. Four-celled embryo with one-celled suspensor.

FIGS. 38–39. Embryos showing periclinal division of dermatogen cells *fig. 39* more highly magnified.



CONRAD on QUERCUS



CONRAD on QUERCUS

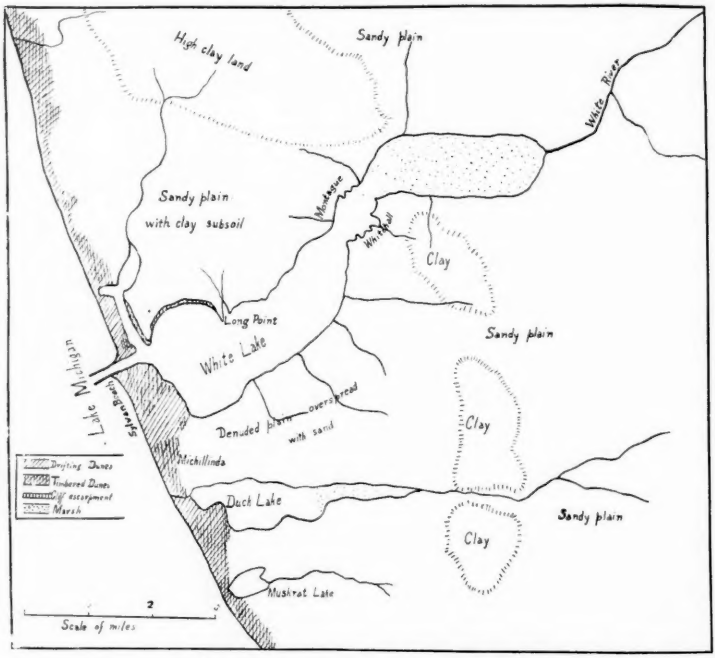
FLORA OF THE WHITE LAKE REGION, MICHIGAN, AND ITS ECOLOGICAL RELATIONS.

(WITH MAP)

E. J. HILL.

WHILE passing the latter part of August 1899 at White lake, Michigan, an opportunity was given to study the flora of the vicinity. It proved interesting in its geographical and ecological relations, and was instructive as a representative example of similar areas by the eastern shore of Lake Michigan, with which I had had more or less acquaintance in past years. White lake is one of those bodies of water, or river-lakes as they have been termed, common in western Michigan, where a stream expands into a small lake before its entrance into Lake Michigan. The river properly ends at the head of the lake where it is bordered by a tract of marshy ground abounding in reeds, wild rice, and various aquatic plants growing in the sediment deposited at its mouth and along its banks, and forming a filling which continually encroaches on the ground once occupied by the lake waters. The lake narrows again into a short outlet of river dimensions when it enters Lake Michigan. If the water of the streams forming them is of sufficient volume these lakes furnish excellent harbors, and become sites of cities and villages, while their shores are often occupied by summer cottages. They are primarily due to the geological structure of the region, dating back to the changes of level which the great lakes were subject to in Pleistocene times. Areas have been worn out by wave action, degraded by meteoric and river waters, or submerged by subsidence, which subsequently have been partly filled by sand driven in by westerly winds aided by deposits at the river's mouth. Such areas do not occur on the western shore of Lake Michigan in Wisconsin and Illinois. The eolian factor is the principal one in the filling process, and the region

is consequently in its surface characters mainly a dune formation. A basin or bay-like area formed in the drift clay of the glacial period is filled with sand above the water level, the lake still occupying a portion of this area. The sand forms a dam



MAP OF THE WHITE LAKE REGION.

This map is based on one published in *The American Geologist* (1 : 143. 1888), in an article "The river-lake system of western Michigan," by C. W. Wooldridge, M.D. Only a few minor changes have been made in the portion of the map used, to indicate better some points covered by the present article.

along the shore of Lake Michigan and across the outlet of the river which impounds the water above. Doubtless the small lake owes its immunity to filling to these dunes becoming timbered before the area could be entirely filled, leaving only a river channel. Vegetation crept in from the surrounding

timbered region which lay above the level of the waters and contested the ground with the wind-driven sand until the dunes by the lake shore, becoming covered and fixed, formed a barrier against further encroachment. The surface sand washed up by the waves of the lake is now piled up on the shore dunes which tend to become higher as long as the tree covering remains as a protection. The study of the flora of such a region is important since it shows the kinds of vegetation which have this ability.

White lake is about five miles long by one to two miles wide, its deepest part being eighty or more feet. It is an expansion of White river. At the entrance of the river into the lake are two villages, Whitehall on the south side and Montague on the north. At the present outlet into Lake Michigan is Sylvan beach, a collection of summer residences, and another, Michillinda, lies just south on the Michigan shore. South of Michillinda are two similar but much smaller lakes, Duck lake and Muskrat lake. The latter is little more than a pond without a visible outlet at present, whose surplus waters must make their way into Lake Michigan by seeping through the sand. The surroundings and flora of these were likewise examined. Lying in the midst of a dune formation their shores are everywhere sandy. The region as a whole is a sandy plain with low ridges of sand more or less parallel, having a north and south trend. Moving or active dunes occur at the southwest side of White lake and by the shore of Lake Michigan. One of these lies between the old outlet of White lake and the lake shore. The natural outlet has been superseded by a short cut into Lake Michigan at Sylvan beach. The original outlet had been crowded northward by drifting sand, and ran parallel with the shore of the large lake for nearly a mile before the water escaped. This is now silted up by sand and the old outlet is a lagoon opening into White lake at its inner end.

Though this dune formation rests on a base of clay the underlying clay rarely appears in sight either by the shores of the small lakes or the contiguous shore of Lake Michigan. Sylvan beach is on a sand covered hill of drift clay, and there are low

escarpments which indicate the presence of the clay elsewhere, as along a portion of the north shore of White lake. One must go five or six miles from the lake to find the clay at the surface except near Montague and Whitehall where it appears *in situ*. The sand of the more level portion varies in depth from two or three feet to twenty-five or thirty or more, rising in low bluffs by the shores of the lake. The line of contact of the clay and sand is best shown by a series of springs along the shore and by the brooks.

This regional structure has its effect on the drainage, and by molding the hydrographic character of the basin has a corresponding influence on the flora. This differs very materially in species and distribution on the opposite sides of White lake. On the south side springs and streams are common, and the clay comes nearer to the surface, especially in depressions between the low sand ridges where the streams mainly occur. On the north side springs and streams are absent except some small ones at Montague. A large brook comes from the clay hills at the north through a rather deep valley lying between the high shore dunes and the main body of the plain, and makes its way into the old outlet of White lake that lay in the same depression. It is a perennial stream of cool water abundantly fed by springs and has the same effect on the flora along its course as does the stream-fed area to the south of the lake. Between this stream and Montague there are no beds even for storm water except near Long point where a couple enter the head of a narrow bay, now a pond and marsh, cut off from the lake by a filling of sand and saw-mill refuse. As they were dry at the time I was there, they were plainly only channels for storm water. The rain as it falls sinks into the sand and makes its way to the lake at or below the water level, or eastward toward Montague and to the perennial brook to the westward.

This indicated a drier region and a greater depth of sand. The flora was correspondingly modified. It was prevailingly xerophytic, ericaceous and arenophilous plants predominating.

On the south side it was much more varied, heath-loving plants mingling more with mesophytic kinds. In the sand plain to the north the tree covering was almost wholly white pine and oak, *Quercus velutina*, *Q. coccinea*, *Q. rubra*, *Q. alba*, and *Q. macrocarpa* being observed, while on the south side, as well as by Duck lake, Muskrat lake, and the valley to the west of the plain, these trees were interspersed with beech, sugar maple, basswood, hemlock, white elm, black ash, white ash, black birch, paper birch, silver maple, tupelo, black cherry, wild red cherry, sassafras, and white cedar. The difference was manifest in the color of the corn in the fields and the behavior of the grass. On the north side the corn was pale and the grass with difficulty made a sod; on the south side the corn had a deeper green, but not the rich green color which comes from a deep firm soil, and the grass sodded fairly well in damper places. But wherever there was a bare surface, as in plowed fields and roadways, the ground showed a sand plain.

The floral societies formed by this mixture did not readily harmonize with ideas of plant ecology based on experience with plants growing in a soil more natural to them and under conditions more uniform. I was familiar with this in the dune region at the head of Lake Michigan, where the herbaceous vegetation is much varied and the arboreous considerably so, but the tree covering south of White lake much exceeded it in variety. It was a surprise to find on the top of a dune, or sand covered hill with a base of clay like that on which Sylvan beach is located, a comparatively pure beech wood. The hill is capped with sand blown up from the neighboring beach. Its south end to some extent still battles with the winds, and owes its immunity in part to their prevailing direction from the northwest, which makes their work more effectual on the north end of the dunes lying toward Michillinda. These dunes, together with the sand washed up in the low interval between, furnish the material of the large active dune now encroaching on White lake. The timbered dune between this opening and Michillinda is high and steep on both sides. Within the space

of a few square rods on the top bordering the part against which the wind was acting I made a list of the following species: beech, sugar maple, red oak, black cherry, hemlock, white pine, white cedar, common juniper, witch hazel, poison ivy, two dogwoods (*C. stolonifera* and *C. Baileyi*), and the willow, *Salix glaucophylla*. On the ground the lesser growth was composed of *Pyrola secunda*, *Arctostaphylos Uva-ursi*, *Polygala paucifolia*, *Aralia nudicaulis*, *Campanula rotundifolia*, *Mianthemum Canadense*, and *Solidago caesia*. The list of herbaceous plants could have been easily increased by walking about a little, but I purposely sat down so as to make a list in sight from a single point of view as a limitation. This was on a narrow crest of sand with a steep timbered slope to the south, and a still steeper one of bare sand to the north extending down to the low area of moving sand a hundred or more feet below. It was possible for all this variety of vegetation to be in time blown away, though the work of the wind was slow, for there was evidence at hand of what it had already done. It was also plain that the plants grew in a soil of sand so little compacted as to be easily moved by the wind when once the covering had been removed.

In the sand plain north of the lake the herbaceous and shrubby flora was less diversified but still well represented in species. Where the oaks prevailed the tree covering was quite open. There were dense groves of young white pine, for the old trees had nearly all been removed to the sawmill. From the stumps which remained it was seen to have been a mixed forest of pine and oak at the time the trees were cut. The undergrowth varied according to the density of the tree covering and somewhat according to its kind, whether of oak or pine. The common wintergreen, the pyrolas, and pipsissiwa were more generally found under the dense growth of pine. The usual ericaceous plants were *Epigæa repens*, *Arctostaphylos Uva-ursi*, *Gaultheria procumbens*, *Pyrola secunda*, *P. chlorantha*, *P. elliptica*, *P. rotundifolia*, *Gaylussacia resinosa*, *Vaccinium Pennsylvanicum*, and *V. vacillans*. In somewhat more fertile areas or deeper humus soil *Monotropa uniflora* was frequent and *M. Hypopitys* was detected

once. The fringed polygala was also frequent, generally in company with the trailing arbutus, which was very abundant, and together they must have made a fine floral display in early May. The polygala occurred under quite different conditions south of the lake, for besides on dunes and the drier sand plain it found a home in the damp sand as a companion of such plants as *Clintonia borealis* and *Trientalis Americana*. *Vaccinium Canadense* also accompanied the other huckleberries in moister areas south of the lake. In the dry plains both north and south were great quantities of *Comptonia asplenifolia*, sometimes quite exclusive of smaller growth. *Pteris aquilina* was equally abundant in spots but not covering such wide spaces as the *Comptonia*. It was the only fern observed in the dry sand plain. *Rhus copallina* was the most common sumach, often much dwarfed and flowering when a foot or less in height. *R. aromatica* and *Shepherdia Canadensis* were frequent along the bluff shores of the lake and occasionally were seen elsewhere in the woods. The most frequent papilionaceous plants of the season were *Lespedeza polystachya* and *L. Stuvei* var. *intermedia*, *Desmodium paniculatum* and *D. nudiflorum*, the latter often under the pines with the pyrolas. The sunflower was chiefly represented by *Helianthus divaricatus*, slender, often dwarfed, and bearing small heads barely an inch in diameter. *Liatris scariosa* was the common blazing-star. The principal goldenrods were *Solidago hispida*, *S. juncea*, and *S. nemoralis*; and the asters mostly *Aster corymbosus*, *A. azureus*, and small forms of *A. laevis*. The round-leaved orchid, *Habenaria Hookeriana*, occasionally occurred, and more commonly *Lycopodium complanatum*.

These were the most typical plants seen in the wooded sand plain north of White lake, a list by no means exhaustive even for the time of the year, but representative of the flora. Nearly all of them were met with on the south side, commonly on the dry sand ridges, and helped to give the flora south of the lake a more mixed and diversified character.

The cool brooks fed by springs, the springy and swampy places south of the lake, had a tree growth in which the white

cedar, black ash, hemlock, cherry birch, paper birch, and white pine were variously intermixed. *Alnus incana*, *Cephalanthus occidentalis*, *Ilex verticillata*, *Pyrus arbutifolia*, *Rosa Carolina*, *Salix discolor*, and *S. cordifolia* were the more common shrubs. The damp shaded reaches along the streams showed such plants as *Mitella nuda*, *Mitchella repens*, *Cornus Canadensis*, *Clintonia borealis*, *Trientalis Americana*, and *Habenaria psycodes*. Here the ferns obtained the proper conditions of growth and occurred in considerable variety. The most frequent were *Aspidium Thelypteris*, *A. spinulosum*, *Osmunda cinnamomea*, *O. regalis*, *Asplenium Filix-foemina*, *A. acrostichoides*, *Onoclea sensibilis*, *Phegopteris Dryopteris*, and *Adiantum pedatum*. Some of these, especially the last two, occurred in the drier area of beech woods along with the Pteris, though this was more abundant in the oak woods. The most interesting fern of the swampy ground was a *Botrychium ternatum*. It was abundant in a locality where the tupelo grew, and where the ground was also closely shaded by a larger fern, *Osmunda regalis*. The botrychiums were from three to twelve inches high, some so hidden that the fronds of the osmunda had to be pulled aside to find them. It was a peaty soil mixed with sand, so charged with humus as to be quite dark colored. Some grew on the hummocks made by the matted roots of the osmunda, the roots of the two ferns being interlaced, but they were more frequently seen in bare spaces between the hummocks, which in the early spring or rainy season must have been quite wet, or even have had water resting on them for a time. Some were growing in soil principally made of the much decayed remnants of a fallen tree. In all conditions it was a soil of a strongly humus composition. This was a surprise to me, for in all previous collections or examinations of this fern the soil had been clay, often a rather stiff clay-loam, or sand as in the dune region east of Chicago. Finding the tupelo led me to search for another plant which I have quite generally found associated with it, *Bartonia tenella*. It was soon discovered on the little hummocks made by ferns, mosses, and other plants, or on abandoned ant hills beneath the trees. The association seems more than casual but may only be due to soil conditions.

The immediate shores of White lake differed considerably in the character of the flora on opposite sides. On the north side was a flat strip of sandy ground, slightly above the level of the water and lying between it and the bluffy shore. It was low enough to be subject to wave action when the winds were strong, or to freshets when the water of the river was high. Here shrubs were scarcely seen, the plants being those of wet sand and shallow pools. *Lobelia Kalmii* was very common. Other representative plants were *Gerardia purpurea*, *G. paupercula*, *Spiranthes cernua*, *Parnassia Caroliniana*, *Juncus Balticus*, *J. Richardsonianus*, and *Carex viridula*. In the shallow pools *Proserpinaca palustris* and *Potamogeton heterophyllus* occurred, the last becoming terrestrial by the drying away of the water. There were similar strips on the south shore, but between the immediate shore and the bluff there were often areas of swampy or boggy land overgrown with willow, alder, and white cedar, dense thickets which showed the influence of the adjacent springs, or of water seeping out from the banks above the clay.

The active dunes had the scanty flora so characteristic of those about Lake Michigan. The plants observed at White lake were mainly *Calamagrostis longifolia*, *Cakile Americana*, *Euphorbia polygonifolia*, *Corispermum hyssopifolium*, *Carduus Pitcheri*, *Solidago Virgaurea* var. *Gilmani*, *Salix adenophylla*, *S. glaucophylla*, *Cornus Baileyi*, *C. stolonifera*, and *Prunus pumila*. As the advance of the dune was very slow the shrubs and perennial plants were not infrequent on the windward side among the annuals much above the base of the dune, showing the ability of the seed to sprout and take root in the sand much exposed to wind action. In fact the favorite place of *Carduus Pitcheri* is everywhere on the windward side of a wind-swept area.

In the lower area of the active dune region lying between the southward bend of White lake and the shore of Lake Michigan, the two above mentioned willows were accompanied by *Salix longifolia*. Here, as frequently elsewhere along the shore, *Salix glaucophylla* had very small much thickened leaves an inch or two long by half an inch or less wide. *Hypericum Kalmianum*

was a common shrub of the locality. *Aster polyphyllus* was abundant and was also seen in higher ground south of the lake. *Cladium mariscoides* occurred in wet places, and several of the plants that have been mentioned for the low sandy borders of the north side of White lake. *Utricularia cornuta* occurred in pools. It was a small sand plain with shallow depressions and low dunes, bare or partially covered with vegetation, an area in which was to be seen a struggle with the destructive winds and a partial success in recovery.

In the deep valley of the brook which joins the old outlet of White lake some interesting forms and associations of plants were found. The white cedar was the common tree in the springy ground. Rills fed by springs along the eastern slope were frequent. Two club-mosses, which are ordinarily seen growing in different societies, were here in company, *Lycopodium lucidulum* and *L. annotinum*. Such a locality is natural to the former, but the latter is usually a denizen of drier grounds, and was here seen in company with *Medeola Virginica*, *Trientalis*, *Clintonia*, and *Viola Labradorica*. The eastern slope was scarped out of the pine plain and was densely covered with white pine and hemlock; the western was made by the high and fixed dunes which form a narrow range between the valley and Lake Michigan, with a flora similar to that of the high dunes south of White lake. In one of the quieter places of the rills a semi-aquatic or floating form of *Marchantia polymorpha* abounded. Some rested on dead leaves and twigs lodged in the water. They were not attached by rhizoids like the ordinary terrestrial form of this liverwort and could be lifted out of the water by the handful like a Lemna or a floating Riccia. The thallus was very thin, especially near the base, the thinnest parts formed of the lower series of cells which enter into the structure of the thallus, the upper or lozenge-shaped layer with the stomates being absent or prevailing in the distal portions. At first it seemed distinct, but the occasional presence of the characteristic cups and gemmules, and the structure as a whole, showed its affinities with the ordinary form found on adjoining logs and earth from which it had spread into the water.

Duck lake is similar to White lake but much smaller. Its southern shore is considerably higher than the northern. The water is clear and quite cool, being well supplied with springs and having only a small stream entering its head. There is a narrow belt of moving sand lying between it and Lake Michigan. To the south are high dunes, skirting the Michigan shore between it and Muskrat lake. The upper end is very reedy, and there is an abundance of aquatics in its shallow parts. In White lake I had found the usual potamogetons to be *P. pectinatus*, *P. perfoliatus* var. *lanceolatus*, *P. lonchites*, *P. amplifolius*, and *P. heterophyllus*. These were also common forms in Duck lake together with *P. natans*, *P. zosteraefolius*, and *P. Robbinsii*. The last had not reached the stage of mature fruit, which is in September and October, but was well provided with flowers and young fruit. This was interesting because it showed that the species may fruit under such conditions as potamogetons ordinarily do. It is usual to find the stems barren, and they are generally said to fruit, if they fruit at all, in shallow water or when ponds in which they grow partly dry up. This was the case in the only locality where I had previously found it fruiting freely, the Chesago lakes, Minnesota. It is very abundant in some of the small lakes of northern Illinois, where the stems are mostly from one and a half to two or three feet long and very leafy. In Duck lake they were less leafy as a whole, the fruiting stems four to six feet long, as this was about the depth of the water. They were rising and bringing the inflorescence to the surface of the water, or near to it, like *P. pectinatus* and the others with which it grew. All were flourishing equally well in the dark ooze which overspread the bottom where they stood, and according to their season were equally well provided with fruit or the promise of it. Nor was there any evidence of the shallowing of the water, except the contrast between summer and the rainy season, not very marked in a lake of this character fed by springs.

The high dunes to the south of Duck lake had on their slopes frequent patches of the yew, *Taxus Canadensis*. On the north slope of one whose base is washed by the waters of the lake it

was a surprise to find *Polypodium vulgare* growing on the sand of the hillside under pines and hemlocks and closely associated with the yew. The beech stood close by. It was strange to get the polypod, the yew, and the beech-drop (*Epiphegus Virginiana*) growing in the same sandy soil and near neighbors. The fronds of the polypod were fine fruiting specimens from three to twelve inches high. It was the first time I had met with it except on rocks. *Aspidium marginale* was likewise a frequent fern on the slope of the hills. It attained a very luxuriant size in the depressions among them, where fronds three feet high were measured. This fern was also common on the east or wooded side of the dune lying between the old outlet of White lake and Lake Michigan, growing here also with the yew under the pines and hemlocks.

South of Muskrat lake is a large fine tract of primitive forest as yet but little touched by fire or the woodman's axe. It is on a sandy, gently undulating, or in places almost level, plain. It is known as the "beech woods," as these trees abound and fine examples of them occur. Being dense the undergrowth was not extensive, but like that of the denser woods lying between White and Duck lakes.

Once I met with the cancer root, *Conopholis Americana*, but the abundant parasite, so-called, in all such woods is *Epiphegus Virginiana*. It is closely associated with the common beech, but I do not succeed in making out any very definite connection between it and the roots of the beech tree. As regards the soil the bulbous or thickened base of this plant is very superficial in position. Some of them have finer roots which run deeper, but the short, simple, or branched organs which cover the surface of the bulb and give to it its rough exterior do not have a root connection. They point in almost all directions and are often found springing from the stem above the place where the scaly leaves appear. The tip of these organs is slightly enlarged, of open tissue without epidermis. There is no similarity here between this and the strong union, or large haustorium, one finds in the case of the allied broom rape, Conopholis, and its host

tree, which I have found to be the oak, or in one case a hickory, and in which the parasitism as seen in section reminds one of that of the mistletoe. There are dozens of these organs on the bulb-like base which lies among the leaves and the humus made by their decay and must be in close contact with them on every side. A saprophytic relation is forcibly suggested, and one connected with beech leaves rather than with the roots of the beech, for the association is always with the beech tree. The leaves have an acid flavor and the wood is one of the best to yield wood vinegar by destructive distillation. The fresh seedlings of the beech, also called beech drops, are pleasantly acid to the taste, and their large cotyledons are eagerly eaten by children as they come up in the spring. It is possible that there is in the beech leaves or the mold made by their decay something which suits the nature of the Epiphegus.

Quite frequent in the beech and oak woods was a mycorhizal plant, *Corallorhiza multiflora*. Its mass of toothed, coral-like roots are buried much deeper in the soil than the bulb of the Epiphegus, sometimes to the depth of two or three inches. Many fine examples of these were seen, some with paler, yellow scapes and flowers, the color reminding one of *C. innata*.

Two introduced plants found in the outskirts of Montague proved of special interest. *Gypsophila muralis* was growing in the dry sand of a little used street. It has the habit of *Arenaria patula*, but a habitat more congenial to *A. stricta* as seen about the great lakes, for I have met with the former only on the thin soil of limestone rocks, where it may be accompanied by *A. stricta*, a common plant of the dune region of northern Indiana. The other immigrant was *Sedum acre*. It formed dense patches by the side of the street and had spread into the adjoining woods, closely covering the ground like a mat, and making an excellent sand binder, green and turfy looking. It was occasionally seen in other places about White lake. As a rock plant I have found it in Illinois in company with *Arenaria patula*.

The physical conditions about White lake and similar tracts of sand-filled depressions along the eastern shore of Lake

Michigan furnish fine illustrations of the ability of plants, and especially trees, to spread from an area where the conditions of growth are more favorable to one where they may be much less so. They emphasize the plasticity of plants. The species may suffer in vigor of growth and have a much less bulk, but they usually fruit very freely, often surprisingly so. At White lake was a basin filled with sand surrounded and underlaid by drift clay, or by materials that enter into the drift formation and on which in our latitude the mixed forests of deciduous species mainly occur. North of the lake, with its deeper and drier sand, the oaks were almost the only kinds to come in and compete with the white pine. South of the lake, where there was more dampness and a nearer approach of the glacial drift to the surface, except on the high dunes, and a more marked tendency to a loamy condition of soil, there were many more kinds of trees and herbaceous plants to share the ground with the pine. But the trees best adapted to a clayey soil not only crept across the area of low sand ridges and the intervening and more favorable hollows but passed up and appeared in force on the high dunes along the Lake Michigan shore, just as they may be seen on a narrow strip of dunes superposed on the clay of the lake shore, where a hardwood forest closely abuts it without any sand-filled basin to the eastward.

I have been struck repeatedly by the distribution of some of the deciduous trees of dune regions, such as that at the head of Lake Michigan in Indiana and Illinois. The basswood is one of the best examples. It appears eastward in the area of broken or active dunes where it is practically confined to a narrow belt by the lake shore and to a similar belt further south along the Calumet river. It frequents the more protected slopes of dunes or hollows lying between neighboring sand hills, though like other trees, from the shifting character of this portion of the dune region, it may be so situated as to give the appearance of growing originally on a crest. West and south it appears again in the area of low sand ridges and shallow lakes and ponds where the conditions are more like those of forest

strips or islands of the prairie region, where it is accompanied by such trees as *Quercus bicolor*, *Q. rubra*, and *Q. acuminata*, additional to the common black oaks which are spread throughout the dune region. Other trees are the hackberry, white elm, tulip tree, shagbark and bitternut hickories, white ash, blue ash and some kinds of Crataegus. Most of these are common trees on the drift clay to the south and west, and all appear somewhere on the bordering clay-land forests, but are scarcely seen in the area of broken dunes, except an occasional red oak, some white oak and bur oak or a bushy form of the Celtis specifically distinct (*C. pumila* Pursh). Lying between these two sections is a strip where the basswood as well as these other trees is absent. There would seem to be sufficient moisture at least, for it is mostly a region of low sand dunes, parallel sand ridges, and intervening sloughs, the ridges with a prevailing heath vegetation. It is the home of the gray pine (*Pinus divaricata*), sometimes almost exclusively so. Where the white pine prevails or shares the ground more freely with the gray pine, the basswood comes in. This is a common tree of the forests to the eastward of these dunes in the drift covered areas, together with the sugar maple, beech, tulip tree, and various other kinds. But nearly all except the basswood and the oaks cease in the belt of less pure sand or sandy loam, lying between the dunes proper and the clay region. There may be in the basswood peculiarities of structure or physiological adaptations better fitting it for xerophytic conditions than the others when they move away from such as are suited to mesophytes. Its leaves become much thicker than when growing in its usual home. There is in the fruit one advantage for more effectual dispersion, the ligulate bract attached to its peduncle, which in a strong wind helps to carry it to quite a distance from the parent tree. Most of the trees which formed the mixed forest to the south of White lake, and like the basswood showed this ability to spread away from a contiguous region more congenial to them, not only fruit freely but have a heavy seed, which, when lying on the surface of the ground, is not easily displaced. Such seeds sprout quickly in

the spring when there is most moisture and when the temperature is moderate. Being well provided with food stored within their coats they can carry on the processes of vegetation till the seedling is well rooted. Thus being more independent of external conditions they have an advantage in establishing themselves in a less favorable environment, such as that of dry sand.

In considering the vegetation of dune areas, especially those of the "Michigan sands," such as appear by White lake, we must also bear in mind that some of them are comparatively well provided with alkaline earths, that all have some amount of these or there would be no tree growth at least. They often produce abundant crops of fruit, especially of kinds that do best in light soil, like the peach. The prevailing constituent of the soil is silex, but microscopic examination and chemical tests show that feldspar, mica, pyroxene, and other minerals are present, such as contain potash, soda, lime, and magnesia, the most important of the alkaline earths. The pebbles of the shingle along the beach are a mixture of various kinds, quartz prevailing, but feldspars frequent, with some limestone. This must be the case since they are mainly produced by the degradation of drift material. The comminuted sands formed from them must necessarily contain the same ingredients, though the harder, coarser, and more resistant quartz sand will be most conspicuous to the eye as well as most abundant. The percentage of ash in the wood of such trees as form the principal covering of a dune region is relatively small. As seen in the analysis reported in the volume of the Tenth Census on the forest trees of North America, the pines have an average range of .19 to .23 per cent. The two most common oaks, *Q. velutina* and *Q. coccinea*, have .28 and .19 per cent. respectively. The white oak and the bur oak are higher but are much less common trees. The leaves and bark would show a higher percentage, but as they fall and the trees decay this is not only restored to the soil but they take with them other important ingredients which enter into the composition of humus. The beech, sugar maple, basswood, hemlock, and some other forest trees likewise stand considerably

higher than the pines and the most common oaks in their percentage of ash, but they, too, are much less common, often wholly absent from large areas. In general, analyses seem to show a smaller percentage of ash in the same species when growing on sandy or gravelly soil than on soils stronger in such mineral ingredients as the trees use, like clay, clay-loam, or lime soils.

But alongside of mineral constituents certain physical conditions are equally important or indispensable. The ability to reach and appropriate what is provided must exist. Porosity, depth of soil, moisture, here come into play. The last is the most important of all in soil conditions, since vegetable life is impossible without some degree of it. For porosity sand ranks the highest, in capability of retaining water it is the lowest, clay being the highest; in capacity for condensing moisture from the air, it is likewise the least powerful, humus and clay being best. In discussing such matters as these, Schlich well states what must have become evident to any who have made a comparative study of the vegetation of the dunes and of the bordering region. Though written with reference to cultivated woods it is as true of the natural forests. "Woods thrive equally well on soils of the most different geological origin, while great differences exist in the development of the same species if grown on soils of the same geological origin. The phenomena are explained by the great importance of the physical qualities of the soil, depth, porosity, and a proper degree of moisture"[1] These conditions go far toward explaining the differences in vegetation seen on the opposite sides of White lake and in corresponding regions, for they are true of vegetation as a whole as well as of the trees. In the case of the trees it was a "mixed wood," but a "mixed wood" of much greater variety on the south side where the physical constitution of the soil as well as its chemical ingredients furnished a more suitable habitat. Though it was throughout a dune formation superposed on a clay substratum, the relations of the vegetation to the substratum were also most

[1] Manual of Forestry 1 : 143. 1889.

favorable on the side of greater mixture. For the roots together with the greater supply of moisture took with this in solution the ingredients which existed in greater abundance in the comminuted soil itself. These beneficial relations also made the forest conditions more favorable in another way, and helped to perpetuate them, as they continually added to the humus, for this was much more in evidence on the side of the greater mixture.

CHICAGO, ILL.

BRIEFER ARTICLES

PHYSIOLOGICAL NOTES. II.

(WITH THREE FIGURES)

3. An artificial endodermis cell.

Since the osmotic pressure depends upon the impermeability of the "semi-permeable" membrane to the solute, it is possible for the osmotically active matter in a cell to exert a different pressure in different directions if the protoplasm is permeable to it in different degree in different parts; and by exerting different pressures it should,

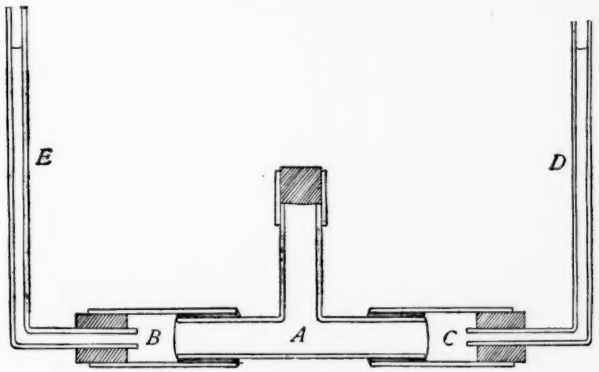


FIG. 1.

when in a state of complete turgescence, take up water where the semi-permeability is most perfect, and pass it off where the pressure is least. This is generally accepted theory, though its clearness may depend somewhat on the reason given for the entrance of the water, but its soundness has not hitherto, so far as I know, been demonstrated experimentally. This may be done as follows: over two ends of a T tube *A*, tie parchment paper; soak one of these ends thoroughly in a solution of $K_4Fe(CN)_6$; seal both ends into glass tubes, *B*, *C*, with communicating tubes, *D*, *E*, bent at right angles, fill the tubes *C*

and *D* with $K_4Fe(CN)_6$; fill *B* and *E* with distilled water, taking care that the liquids stand at the same height in *D* and *E;* fill *A* with $CuSO_4$, and close it. The membrane containing $K_4Fe(CN)_6$ is promptly filled with a precipitate of $Cu_2Fe(CN)_6$ which is practically impervious to $CuSO_4$, and any leak in this precipitation membrane will be immediately mended. The other membrane, of parchment paper alone, is relatively easily passed. The pressure against it is accordingly less. I have worked the experiment using 6 per cent. $CuSO_4$ and 3 per cent. $K_4Fe(CN)_6$. After 2 hours 15 minutes, the $K_4Fe(CN)_6$ column had fallen 1^{mm}, and the column of water had risen the same distance. Wishing to stop while the water was as pure as possible. I poured it out then, and was unable to detect any copper in it with $K_4Fe(CN)_6$; it may have been there in extreme dilution, or it may have passed into but not yet through the membrane. What had been done then was taking water out of a solution of appreciable osmotic strength, and forcing it over into practically pure water. The energy to perform this work is furnished by the loss of $CuSO_4$ from the T tube, as is easily seen if the experiment is continued longer. The concentration of the solution that is forced through the parchment membrane must obviously be at first slightly in excess of that of the $K_4Fe(CN)_6$ that the water is drawn from.

The experiment is interesting in botany, because root pressure must be caused by exactly this same process. Under certain very unlikely conditions, differences in temperature, without any loss of dissolved matter, might cause guttation, but they could not cause root pressure, because all parts of the root must be at too nearly the same temperature. That any sort of "pulsations," without variations in the resistance to the escape of the solute, could cause root pressure, will appear impossible until some adequate source of energy is shown, and if the solute escapes it is unnecessary to imagine rhythmic or any other variations. As Pfeffer suggests, pure water might be forced from a cell by local internal differences in concentration, but it would require energy whose source is unsuggested, to set up and maintain these differences.

In order that root pressure may be caused in the way that the experiment with this artificial cell illustrates, the protoplasm must be permeable to the osmotically active matter of the cell sap in different measure in different parts of itself—which is not much to expect of protoplasm, which shows a finer development of the power of internal

local differentation, for instance, in the asymmetrical growth of the wall. This power of the protoplasm might be exercised only by certain tissues or cells, as the "passage cells" of the endodermis, but probably it is by no means so restricted.

Further, the solution given out under pressure must be more concentrated than the water that enters to take its place. This does not mean, though, that if, for instance filtration is from the endodermis, the sap in the xylem must be more concentrated than the cell-sap in the cortex. For all the living cells from the root hair to the wood may cooperate as a unit, so that if the solution in the xylem is just enough stronger than the water *in the ground* to overcome the slight resistance to its passage offered by the intermediate tissues, all the physical requirements are satisfied. It is likewise absolutely unnecessary that the deeper cortical cells have more concentrated sap than the root hairs, in order to withdraw water from them; although it is usually the case that the turgor increases from the epidermis inward. When an epidermal cell has taken in all the water it can hold, the underlying cell has only to contain cell sap osmotically stronger than the ground water in order that a stream may pass through into it.

The energy which the cells exerting root pressure lose in the filtration of a part of their osmotically active matter is not (except, in part or in whole, in guttation and bleeding) a real loss to the plant. It is returned when the water and solute are separated by evaporation. So that when root-pressure raises the transpiration stream, just as when any other method — capillarity, suction, imbibition, etc. — is used, the ultimate source of energy is those rays from the sun that evaporate the water. In extreme cases root pressure amounts to an atmosphere or so. The solute necessary to explain this will have no discernible effect upon the amount of transpiration, being too insignificant beside the energy always used in evaporation, which is sufficient at ordinary temperatures to lift the mass of water evaporated, without any change in its condition, about 140 miles.—

4. The self-registration of photosynthesis.

The employment of the graphic method has proved an invaluable aid in many fields of physiological research, and has at the same time been of even more general, if of less intense, utility as a feature of class demonstration. The very simple device described here, by which the method is extended to the new field of photosynthesis,

appeals at first sight to its availability for popular demonstration. Even for purposes of investigation it is free from most of the objections to the bubble-counting method, and subject only to such as necessarily attend work on water plants.

Submerged plants of some kind are fastened where the oxygen they set free as gas is collected under an areometer. They may be fastened

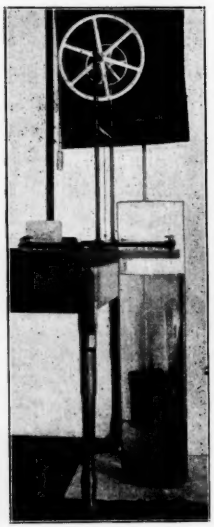


FIG. 2.[1]

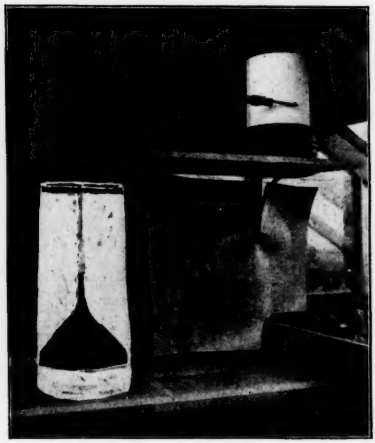


FIG. 3.

into a funnel, whose upper end is sealed into a tube of uniform external diameter, closed at the top (*fig.* 2). Or they may merely be tied into a beaker, or any other vessel, which is inverted and hung by a uniform rod. Because it is allowed to contain air, or preferably as it is held up by a counterpoise, this funnel or other vessel containing the plants stands with the uniform tube partly out of the water. As the plant assimilates, the oxygen set free displaces water, making lighter the vessel with its contents, which accordingly rises, lifting above the water a volume of the tube or rod equal to that of the oxygen evolved in the water below. It is indifferent whether the bubbles rise and

[1] Used by courtesy of the West Virginia Experiment Station.

collect in the tube or against the top of the beaker, as the larger ones do, or remain clinging to the leaves; or if only they displace water, they may stay within the tissues of the plant, and still make their record.

Of course having a rod whose upward movement shows the rapidity of the evolution of oxygen, it can very easily be made to leave its record; most accurately perhaps by means of the wheel described as the chief part of a "a new self-registering transpiration machine,"[2] but more conveniently sometimes, being less disturbed by drafts, by means of a lever auxanometer. One illustration shows it set up with a Corbett auxanometer (*fig. 2*); the other, with the wheel (*fig. 3*).

From a considerable bulk of green plant substance the evolution of oxygen is so rapid that it is necessary to use a rather large rod or get an inconveniently rapid drop of the tracer. With the auxanometer it is better to have the arms of the lever equally long. And with the wheel the tracer may be attached directly to the counterpoise, thus using only one wheel. I have tried the apparatus with Elodea and with Callitriche. The short record given here as an illustration of its work was obtained with Callitriche, May 10, beginning at 11:20 A. M., after a freezing night. The experiment was performed on the the roof, so that there were no shadows except from occasional clouds. The distance descended by the tracer and the indicated evolution of oxygen are both given. A change in weight of 1 ^{gm}, by the evolution of 1 ^{cc} of oxygen, caused the tracer to fall 17.7 ^{mm}. The registration was on a cylinder revolving in 20 minutes, but for the sake of brevity the record is condensed into one hour intervals. The temperature at 11 A. M. was 19°C.; at 1 P. M., 23°; and at 7 P. M., 21°.

	11:20–12	12–1	1–2	2–3	3–4	4–5	5–6	6–7	6:40–7
mm.	6.8	14.8	28.7	32.2	37.8	31.8	21.0	11.2	1.7
cc.O.	0.37	0.84	1.62	1.82	2.14	1.80	1.19	0.63	0.096

With the same plants on another day it was found that at 31° the evolution of oxygen was above 3 ^{cc} per hr., while at 36.4° it was only about 1 ^{cc} in the same interval. The explanation must be sought largely in the decrease in available CO_2 at the higher temperature.—EDWIN B. COPELAND, *University of West Virginia, Morgantown.*

[2] BOT. GAZ. **26**:343. 1898.

CURRENT LITERATURE.

BOOK REVIEWS.

Pfeffer's Physiology.

ALMOST as soon as the German edition of this great work appeared, announcement was made that it would be translated into English by Professor Ewart. The two years that have elapsed since the German edition was published have only whetted the desire of English-speaking students to have the work in a more familiar tongue, because they have found out how intricate and obscure the style of the original is. There is no need to speak again of the contents or value of the work itself.[1] Use of it has amply justified the enthusiastic reception with which it was greeted by students everywhere. Doubly welcome, therefore, is the elegant volume now before us, faultless from the bookmaker's point of view. One must pay for such elegance, however, and we would that the English edition had been kept down to the price of the German, instead of the almost prohibitive $7.00. The necessity of having both — German for what Pfeffer says and English for what Ewart says he says — makes the high price the greater burden.

For when one compares the English text with the original he is immediately impressed by the fact that this is not a translation in the usual sense. Indeed, the translator says in his preface: "The difficulty of the original German has necessitated the exercise of a certain freedom in the process of translation, but an exact interpretation of the original has been given throughout." No one could expect a literal translation of the original, and we are grateful that a free rendering in smooth idiomatic English has been made. While we here acknowledge to the full the indebtedness of students to Dr. Ewart for time and labor which he has expended to put before them this English version, it will not be considered ungracious, if for the benefit of users we raise the question whether it was necessary to take as many liberties with the text as the translator has done. These consist in the addition, omission, and alteration of qualifying words and phrases, to such an extent as often to make it questionable whether or not a given passage is "an exact interpretation of the original." Forewarned of this freedom of interpretation, it will be necessary for one to refer to the German text to determine for himself precisely what Pfeffer says, for it is these very qualifications which restrict or color his statements. Specific cases might be cited in almost unlimited number, were it not easy for anyone who cares to verify the statement to find

[1] See BOT. GAZ. **25**: 132. 1898.

numerous illustrations. The opening paragraph of § 49 may be taken as a fair example of general "interpretation." For instances of alteration take these two: "unvollkommenen Bundeln" of mosses (p. 197) is rendered "rudimentary vascular bundles (p. 216). Pfeffer would probably deny the morphological implication in the latter phrase; at least he had avoided it in his use of the original adjective. Again: "nachweisbaren Producten" of photosynthesis (p. 299) are not necessarily "visible products" (p. 317), and the change makes the sentence untrue. Nor will it be fair to consider the passage of the English proofs through Pfeffer's hands as equivalent to an endorsement of the translator's particular modes of expression.

The comparison with the original is necessitated further by the avowed changes which Dr. Ewart has wisely introduced. In the main these are indicated by brackets, but this should have been uniformly done. The later literature is cited and other betterments are noticeable. The avoidance of new terms is desirable whenever it does not involve too great circumlocution, and the new book has practically none. We note, however, the increased use of photosynthesis, which is making its way in spite of conservatism, though it is not used consistently. Ewart is in error regarding the term photosyntax (footnote, p. 302), which he rejects as unnecessary. It was defined by the proponent precisely as photosynthesis (p. 292), and could by no means include "all cases of carbon dioxide assimilation."

Some of the slips of the German text have been corrected, but two notable ones in § 40 have been missed. On p. 250 the amount of water transpired under favorable conditions is given as 1 to 10^{cc} per 24 hours "from a single square *centimeter* of leaf surface." This should read decimeter, the amounts named being 100 times too large. On p. 251 also the last two sentences of the middle paragraph should be transposed, the last one being meaningless in its present position.

Inasmuch as the cross-references are to sections it would have been convenient to have the section numbers in the page head, as in the German book. This disadvantage is much more than balanced, however, by the very complete index, an essential feature absent from the original.

The second volume is awaited with the greatest interest, and we trust the English version will appear promptly as promised. And we must not allow any differences of opinion or defects in the translation to minify our obligations to Professor Ewart and to the Clarendon Press for the helpful and elegant volumes.—C. R. B.

NOTES FOR STUDENTS.

Dr. J. Loeb has begun the publication of a series of articles containing new facts and ideas concerning the constitution of living matter, to which the attention of botanists should be directed. The first one,[2] on the poisonous

[2] Am. Jour. Physiol. **3**: 327–338. 1900.

character of a pure NaCl solution, points out that the salts or electrolyte in general do not exist exclusively as such in living tissues but are ionized, and these ions are united with the proteids. "The great importance of these ion-proteid compounds lies in the fact that by the substitution of one ion for another the physical properties of the proteid compounds change. This accords with Dr. Loeb's own results on variable absorption of water by muscle, according as Na, K, or Ca ions were present, and explains some facts regarding the effects of salts upon turgor in plants. Loeb found pure NaCl solutions of equimolecular strength with sea water poisonous to Fundulus, a fish which can endure a great increase in the concentration of sea water, even an addition to it of 5 per cent. NaCl, while in distilled water young fish lived indefinitely. (True had previously shown that NaCl and KNO_3 are poisonous to Spirogyra.) He also found the medusa of Gonionemus non-contractile in NaCl, and was able to control its contractility at will by varying the solutions; ciliary movement and development in young larvae of the sea urchin could be modified in the same way. Loeb's conception as to the relation of metal ions to proteids and the protoplasmic functions suggests reexamination of the conclusions as to the elements necessary to the healthy development of plants. These conclusions have been based chiefly on the use of nutritive solutions from which certain salts were successively omitted. One element, however, may only be necessary to antagonize the action of another.—C. R. B.

THE FOURTH PAPER in Professor F. O. Bower's series entitled "Studies in the morphology of spore-producing members," deals with the leptosporangiate ferns.[3] The preceding papers dealt with Equisetineæ and Lycopodineæ (published in 1894), Ophioglossaceæ (in 1896), and Marattiaceæ (in 1897). The importance of the present contribution, dealing with the greatest of the pteriodphyte groups, can hardly be overestimated. In our limited space it is impossible to note a tithe of the interesting observations and suggestions. It will be remembered that Professor Bower excludes both Isoetes and Ophioglossaceæ from the Filicales, and in the present paper he only considers the homosporous forms. As thus limited, he proposes the three following great divisions of homosporous Filicales, which he calls suborders: *Simplices*, *Gradatae*, and *Mixtae*.

It may serve to a better understanding of the characters upon which these divisions are established to indicate the groups which they include. The *Simplices* include Marattiaceæ, Osmundaceæ, Schizæaceæ, Gleicheniaceæ, and Matonineæ; the *Gradatae* include Loxsomaceæ, Hymenophyllaceæ, Cyatheaceæ, Dicksonieæ (exclusive of Patania, Woodsia, Hypoderris, and Deparia), and Dennstaedtiinae; the *Mixtae* include Davallieæ (exclusive of

[3] Phil. Trans. Roy. Soc. B. **192**: 29–138. *pls.* 2–7. 1899. London: Dulau & Co., 37 Soho Square, W. 8*s*.

Microlepia), Lindsayeæ, Pterideæ, and other Polypodiaceæ, together with Woodsia, Hypoderris, and Deparia.

It is noted with interest and approbation that the terms Eusporangiatae and Leptosporangiatae are dropped as designating systematic divisions, but retained as descriptive words. The difference in the mode of origin implied by these terms is regarded as marking no important biological feature, whereas the distinction between the three groups proposed rests upon facts of far-reaching biological significance, and conveys in each case a definite morphological conception.

In the *Simplices* the sporangia are of simultaneous origin, upon a receptacle which may be slightly sunken, flat, or slightly projecting; also, they are of relatively large size, sessile, and usually produce a large output of spores (ranging from 128 to over 7000). The annulus when present is oblique, and dehiscence is in a median plane, correlated with freedom for lateral spreading. The protective arrangements are usually absent or inefficient, and the whole group is to be regarded as displaying primitive characters.

In the *Gradatae* the sporangia are borne in basipetal succession, with regular orientation, upon a more or less elongated receptacle; also they are usually of smaller size, sessile or with short stalks, and the output of spores is typically sixty-four or lower. The dehiscence is lateral and oblique; and the annulus is oblique, correlated with freedom only in a direction obliquely upwards. In general the indusium is present as a basal cup or basal flaps.

In the *Mixtae* the sporangia are of various ages intermixed, without regular orientation, upon a sunken, flat, or slightly projecting receptacle; also they are relatively small, with more or less elongated and thin stalks, and the output of spores is sixty-four or under. The annulus is vertical, and the dehiscence transverse, correlated with freedom directly upwards. The protective arrangements are various, and often elaborate.

These three divisions the author regards as illustrating the three steps in the evolution of the sporophyte in homosporous Filicales. He does not suggest a single line of descent, but rather parallel development, the members of each of the three divisions not necessarily being of common descent, but grouped according to common adaptation, just as are the seed-plants.

It would be profitable to consider the summaries of information given under each group; also the morphological discussion of the sorus, including the indusium, the receptacle, and the sporangium with its stalk, annulus, and output of spores; and also the discussion of the biology of the sorus, which includes the production and nutrition of spores, their protection till maturity, and their dispersion; but for all these interesting topics the original paper must be consulted.— J. M. C.

Mr. W. A. Cannon has published the results of a morphological study of the flower and embryo of *Avena fatua*, the wild oat (Proc. Calif. Acad.

III. 1 : 329–364. *pls. 5.* 1900.) The investigation of some of the grasses from the modern morphological standpoint has long been a *desideratum*, as they have had the reputation of being exceptional in certain features, and because of the question as to their primitive or reduced character. The author states his results in a remarkably clear and well organized summary, from which certain points bearing upon mooted questions may be noted. The lodicules are regarded as stipular rather than "perianthal;" the earlier growth of the stamen is mainly intercalary in the anther; the staminate archesporium is composed of a single row of cells, and each spore mother cell touches the tapetum; the wall of the microsporangium consists of tapetum, middle layer, and endothecium; the generative nucleus divides in the pollen grain, and the male cells are elongated spindle-shaped; the archesporial cell of the ovule cuts off no tapetum; the four potential megaspores are formed in various ways, (1) by four nuclei without cell walls, (2) by the development of four nuclei which later are separated by walls, (3) by the usual appearance of walls following each nuclear division, in which features there is a close resemblance to Eichhornia as investigated by R. Wilson Smith; the antipodals multiply before the fertilization of the egg, becoming thirty-six or more in number, and begin to disorganize with the beginning of endosperm development, apparently serving to nourish the forming endosperm, as that in turn nourishes the embryo; the endosperm first aggregates about the forming embryo, a fact which seems to be correlated with the feeble development of the suspensor, which consists of but a single cell; in its development the embryo of *Avena fatua* illustrates all three of the "types" of Nörner; the cotyledon and the stem-apex are derived from the distal segment, the root, the root-cap, and periblem initials of the root from the middle segment, and the coleorhiza from the basal segment; the organs of the embryo originate in the distichous manner characteristic of the vegetative leaves of grasses.

It is to be regretted that the author's material did not permit him to determine the fate of the second male cell, especially in a family in which the phenomenon of xenia occurs, which seems to be best explained as an evidence of double fertilization.—J. M. C.

DR. ARNOLD GRAF objects to the term cytology as far too general, and proposes the following subdivisions of the subject: cyto-morphology (external form and size); cyto-anatomy (organization); and cyto-physiology. The latter is further divided into *a*) cyto-mechanics (physical properties and behavior to mechanical stimuli), including cyto-statics (conditions of equilibrium) and cyto-dynamics (phenomena of motion, including cell-division maturation and fertilization, death and *pro parte* pathology); and *b*) cyto-chemistry.—C. R. B.

NEWS.

DR. JULIA W. SNOW has been appointed instructor in botany in Rockford College, Illinois.

MR. FREDERICK O. GROVER has been promoted to the professorship of botany in Oberlin College.

DR. RODNEY H. TRUE has been appointed lecturer in botany at Harvard University during the absence of Dr. George L. Goodale next year.

PROFESSOR JOHN BRETLAND FARMER, of the Royal College of Science of London, has been selected by the Royal Society for election to membership.

THE INTERNATIONAL ASSOCIATION for the Advancement of Science, Art, and Education will hold its first assembly in connection with the Paris Exposition. In the long list of congresses, that of botany is announced for October 1 to 6.

MR. CHARLES E. SMITH, one of the prominent botanists of Philadelphia, died recently. By his will the Philadelphia Academy of Natural Sciences receives his botanical library and herbarium, and one sixth of the estate, which is estimated at $500,000.

TWO SETS of Bailey's *Cyclopedia of American Horticulture* are being cut up and pasted on sheets in the economic herbarium of the Department of Agriculture. This will give a working list of *desiderata* for the cultivated plants of the United States.

THE LAST *Bulletin of the New York Botanical Garden* (1: [no. 5] 295–449. *pls. 10–12.* 1900) contains the various reports for 1899. From them we learn that during the year the herbarium received accessions of specimens to the number of 70,000; and that over 4000 species and varieties of plants are under cultivation in the various plantations, 172 families and 1057 genera being represented.

DR. B. M. DUGGAR, of Cornell University, has received the appointment from the Smithsonian Institution, to the research table at the Statione Zoölogica, Naples, Italy, and has already entered upon his work there. He has been in Europe during the past year, has visited England, Sweden, Germany, and Italy, and has been studying at Leipzig and Halle until his departure from the latter place for Naples. He expects to return to Cornell University in July.

THE FIRST ISSUE of the *Popular Science Monthly*, that for June, under the editorial management of Dr. J. McKeen Cattell has appeared. It gives promise of a strong grasp upon a very important constituency, one which is eager to read about science and is in peculiar danger of being imposed upon by science "falsely so-called." The editor and the long list of men of science who have promised to support the journal are a guarantee that the standard will be very high, and that the contents may be depended upon. In this number Professor D. T. McDougal has given an interesting and well-illustrated account of The New York Botanical Garden, and several botanical reviews appear.

IN THE *Journal of Botany* for June (pp. 224–229) there is reproduced an overlooked paper by Rafinesque. It is not included in Dr. R. E. Call's account of the *Life and Writings of Rafinesque*, is not in the Royal Society's *Catalogue of Scientific Papers*, and several names in the paper are not to be found in the *Index Kewensis*. It was published in Loudon's *Gardeners' Magazine*, nineteen volumes of which appeared (1826–1843). The title of the paper is "Remarks on the Encyclopædia of Plants of Loudon, Lindley, and Sowerby," and the citation is Loudon's *Gard. Mag.* **8**: 245–248. 1832. The comments are in the usual style of Rafinesque, very brief but very direct, and it will be a matter of interest, as Dr. James Britten suggests, to collate the names with the *Kew Index* and with American nomenclature. The paper closes with the characteristic statement that "Botany will never be permanently fixed until all errors are exploded and corrected."

GENERAL INDEX.

The most important classified entries will be found under Contributors, Disease, Personals, Reviews, and Work. New names, and names of new genera, species, and varieties, are printed in **bold-face type**; synonyms in *italics*.

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